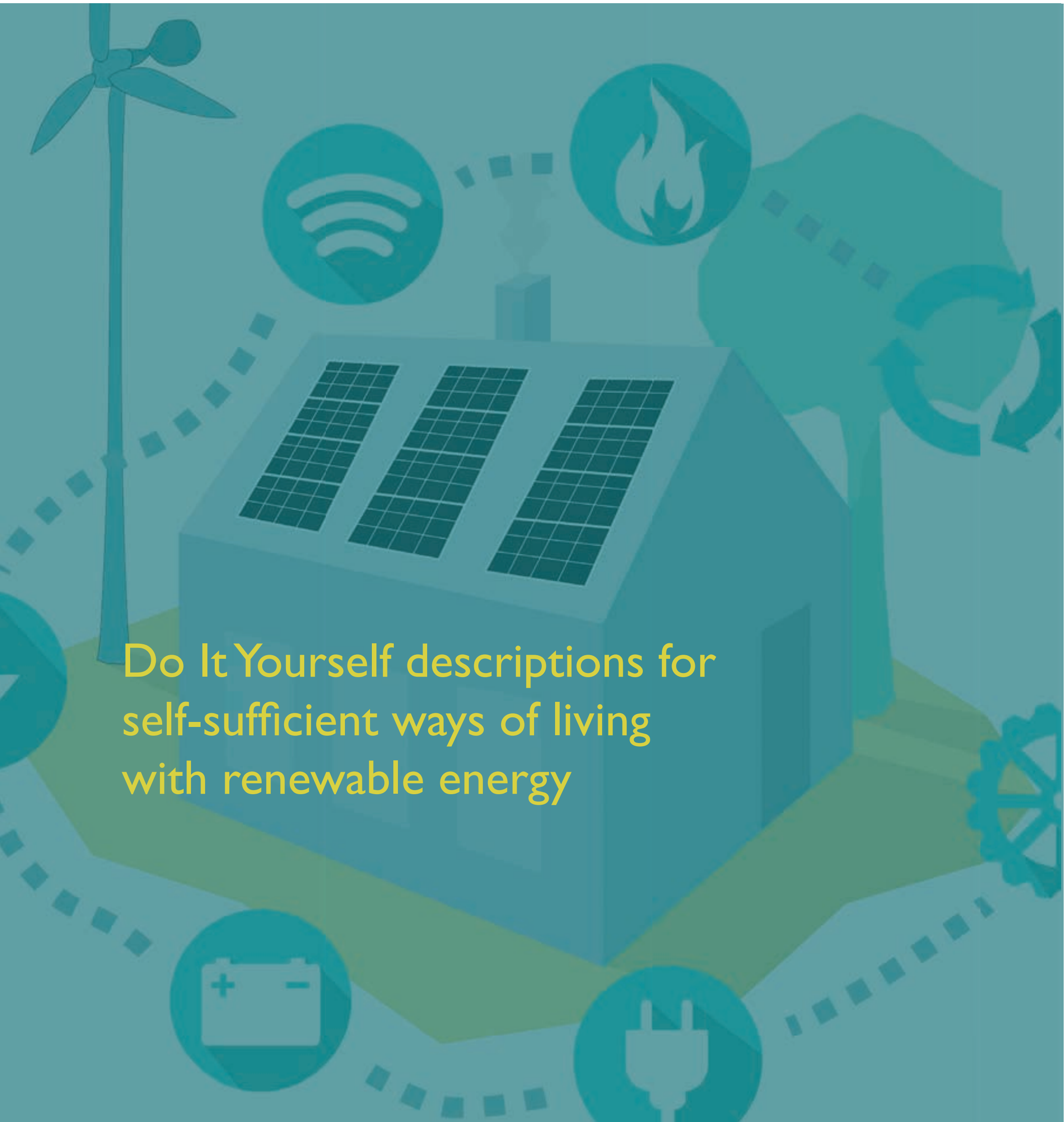
Off-Grid DIY Renewable Energy for Rural Development

SOLUTIONS HANDBOK



Do It Yourself descriptions for self-sufficient ways of living with renewable energy

This paperback, first edition, was published in 2020

The print and it's content is a result from the LEADER funded project Off-Grid DIY Renewable Energi for Rural Development, combined with pro-bono contributions from it's partners.

The European Agricultural Fund for Rural Development: Europe investing in rural areas

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Wood gasifier	combined heat and power emergency system

1. Introduction

Welcome to this printed book, one of the results from the LEADER funded project Off-Grid DIY Renewable Energy for Rural Development. Maybe this title is giving you a rough description of the content, but we will of course try to also give explanations and descriptions of the terms and project in these first chapters of the book as well.

Background & Project description

The initial part of the Off-Grid DIY project has been happening during 2019 - 2020, when actors and partners from countries around the Baltic sea have met and exchanged knowledge through workshops and planning-meetings .These actors have both had an interest in communicating and sharing their own experiences and experiments from renewable energy-solutions, while at the same time wanting to learn from others.

The first part of the project has been funded by the European Agricultural fund for Rural Development through LEADER and it's LAG's (local action groups) in Sweden, Finland, Estonia, Latvia and Lithuania.

The seeking of new funding will hopefully mean that the project can continue to grow and include even more nations, actors and activities in the future.

The Goal

The main goal has not just been to create a book that might be printed once, with content that is not being updated in a world that is undergoing alot of change. The goal has instead been to create a website and online platform where technical solutions can be shared. These can then be developed and optimised as new versions or systems are installed and more experiences gathered, by and from all of us.

The book that you are now holding in your hands only contains descriptions of a few of these solutions and is meant to be an inspiration for you to continue to the online platform and discover more. Hopefully you will also feel inspired to engage in a community where curiosity for finding smarter ways for living with energy is shared, in a world with less waste and dependency of fossil fuels.

We hope to see you on the online platform soon

www. off-grid.rocks

Presentation of LAGs

Before we move on to the renewable energy introduction and technical solutions, we will show the LAGs that has been involved in the project, their project activities and some of the key partner organisations that has contributed with solutions and technical expertise.

2. Presentation of partner LAGs

Name of the LAG and country:

Hiiumaa LAG, Estonia

Contact person for more information about the Off-grid DIY project in the LAG region:

Ilmi Aksli
ilmi@kogu.hiiumaa.ee
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Solution prototype(s) built within the Off-grid DIY project:

Innovative Solar House TRIAN-S

Solution experts involved:

Tonis Kasemagi
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Name of the LAG and country:

Lag Pyhäjärviseutu ry, Finland

Contact person for more information about the Off-grid DIY project in the LAG region:

Elina Haavisto - LAG manager
elina.haavisto@pyhajarviseutu.fi

Solution prototype(s) built within the Off-grid DIY project:

Biomeiler
Solar dörren

Solution experts involved:

Jukka Kontulainen,
ProAgria Western Finland
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+358408298135
(solar collector, biomeiler)

Name of the LAG and country:

Abulas area partnership, Latvia

Contact person for more information about the Off-grid DIY project in the LAG region:

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+371 26555539

Solution prototype(s) built within the Off-grid DIY project:

Off Grid / on grid PV-panel system

Solar collector

Pedal Power:
- > Velo-mobil/Velo-rickshaw with electric powertrain
- > Table with pedal-power generator
- > Cargo bike
- > Velo washing machine
- > Velo grain mill
- > Velo vegetable/fruit grinder
- > Velo waterpump

Activities during the project period (2018-2020):

Workshops about: Off Grid / on grid PV-panel system DIY, Solar collector DIY, Pedal power

Conference about renewable energy in small households

Solution experts involved:

Pedal Power:
Elgars Felcis
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Gatis Kreicbergs
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Off Grid / on grid PV-panel system:
Indrek Roasto
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Solar collector:
Andrejs Snegirjovs
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Name of the LAG and country:

Aktion Österbotten Rf, Finland

AKTION ÖSTERBOTTEN

Contact person for more information about the Off-grid DIY project in the LAG region:

Shiva Sharma
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Solution prototype(s) built within the Off-grid DIY project:

Biomeiler and hot water energy storage system prototype build to connect with complex off-grid solution in Meteoria Söderfjärden, Vaasa

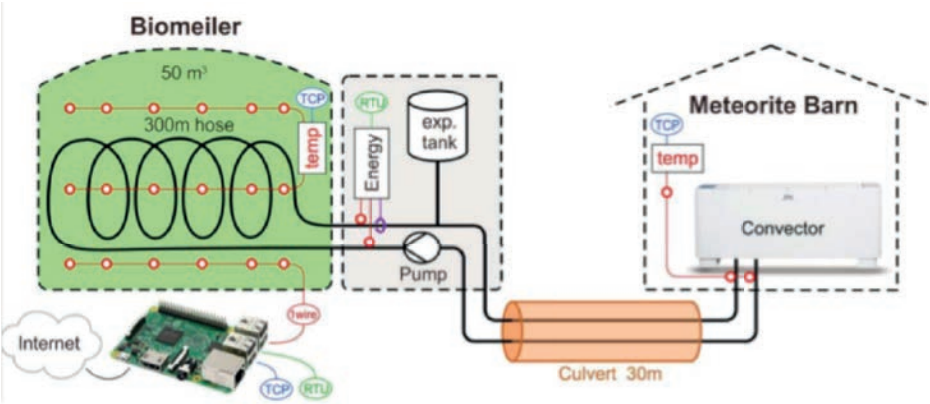
Activities during the project period (2018-2020):

Workshop building the biomeiler with local people from Sundum village.
Introduction to off grid system and biomiller in Meteoria to local newspaper.

Solution experts involved:

Hans Linden
Jukka Kontulainen
Cynthia Söderbacka
Shiva Sharma

NOVIA UNIVERSITY OF APPLIED SCIENCES


Biomeiler
50 m³
TCP
300m hose
temp
RTU
Energy
exp. tank
Pump
Meteorite Barn
TCP
temp
Convector
1wire
Internet
TCP
RTU
Culvert 30m

Name of the LAG and country:

Oulujärvi LEADER, Finland

Contact person for more information about the Off-grid DIY project in the LAG region:

Mari Korhonen
mari.korhonen@msl.fi

Solution prototype(s) built within the Off-grid DIY project:

PV/solar photovoltaic system (installation)
"solar door" / solar hot air collector

Activities during the project period (2018-2020):

Participation in meetings in Latvia, organising a project workshop in Säkylä, Finland, in September 2019.
Construction of a biomeiler prototype.

Solution experts involved:

Jukka Kontulainen,
ProAgria Western Finland
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+358408298135
(solar collector, biomeiler)

Janne Käpylehto
(solar energy)

Project partner

Maaseudun Sivistysliitto /
Union of Rural Culture and Education

Name of the LAG and country:
Parnu Bay Partnership, Estonia

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+372 517 7174

Solution prototype(s) built within the Off-grid DIY project:
Emergency solution for combined heat and power generation using woodgas

Activities during the project period (2018-2020):
Presenting reed briket DIY production on bio-diversity days.
Presenting off-grid DIY project on community energy and bio-energy events.
Workshop of building the woodgas emergency generator
Stirling engines study and solution promotion
Energy storage solutions study and report (available online)

Solution experts involved:
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Peeter Viik

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Name of the LAG and country:
Association Kaišiadorys district LAG, Lithuania

Contact person for more information about the Off-grid DIY project in the LAG region:
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Solution prototype(s) built within the Off-grid DIY project:
Principles and installation of solar collector system
Principles and installation of solar power plant
Practical education for children „Wind Challenge“
Practical education for children „Sunstroke

Activities during the project period (2018-2020):
Meeting with partners in Latvia, Finland and Estonia.
Trips of project participants to Finland and Estonia.
Filming and publishing of 4 educational films from workshops
Conference „Renewable Energy for Rural Development“ in 2020.

Solution experts involved:
Mantas Marciukaitis, Head of the Laboratory for Renewable Energy and Energy efficiency
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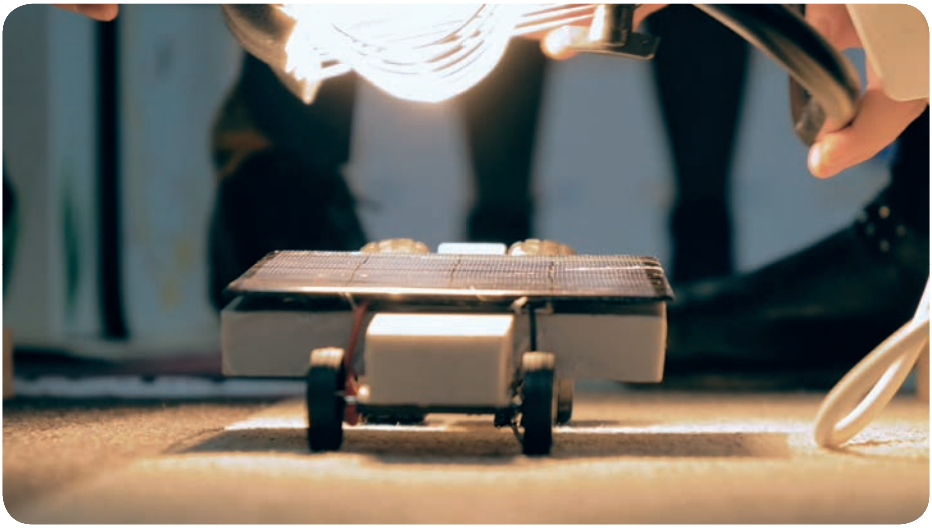


KONFERENCIJŲ CENTRAS

Name of the LAG and country:

LEADER Gute, Sweden

Contact person for more information about the Off-grid DIY project in the LAG region:

Mikael Håkansson
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Solution prototype(s) built within the Off-grid DIY project:

Puxin Biogas-digester
Rocket Thermal solutions
Piggott Wind turbine

Activities during the project period (2018-2020):

Dissemination-seminars on possible solutions within Renewable Energy with experiences from other regions.

Providing deliverables (web, book and video) for the Off-Grid DIY project through sub-contractor RELEARN Suderbyn.

Workshops and installations connected to above mentioned solutions through project partner RELEARN Suderbyn.

Activities and Off-Grid development connected to Austerland Energy on Gotland, Sweden.

Solution experts involved:

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(rocket solutions, Puxin biogas)

Robert Hall, RELEARN Suderbyn
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(Puxin biogas)

Simon Goess, SG Consult
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(Piggott wind turbine)

RELEARN SUDERBYN

3. Explaining the terminology

Even though you might already be familiar with the terms above, we want to start with clarifying how we use them here.

Off-Grid is often used to describe a home, building, village or other kind of human development that's not connected to a central electrical grid or other infrastructure (heat, water, sewage). It also often means that something is, or tries to be, more or less selfsufficient in terms of meeting these needs,.

When we use the term off-grid here, we often mean exactly this, but we also recognise that some of these solutions and systems also can be connected to a grid. This might be so that they can provide excess renewable electricity to others, while having the option to go off-grid when wanting so. A grid can also be of smaller, local scale, with shared resources and investments among the actors. This can sometimes be a better option than if everyone built their own systems in a rural development, depending on the local conditions.

DIY is short for "Do It Yourself", which often means that something can be done without specific knowledge, professional background or certifications. As it will be explained in some solutions, this might however not always be true and some solutions, depending on local regulations and laws, might need specific certification or permits (e.g electrical work or installation of biogas).

Always make sure that you are aware of local regulations, and always put safety first when working with tools, equipment or building the solutions!

Can’t or don’t want to do the work yourself?

Maybe you want to have some of these solutions built or installed, but can’t or don’t want to do the work yourself? We hope to be able to connect people throught the platform and community for this reason, so stay updated with the online platform and discover if you can find help in your area.

Renewable energy is the term for energy-production that is not based on using fossil-fuels (e.g. oil, petrol, coal or natural-gas). This energy can either be electrical, thermal/heat or mechanical and the sources can for example be sunlight, wind, water (sea, rivers or reservoires) or biomass (wood, waste-material or biogas).

When we speak about renewable energy and different technical solutions, we should be aware that they also can be harmful for ecosystystems and pollute. This can for example happen through the release of greenhouse gases when they are produced (materials and parts), while being used (infrastrucure and transportation) or when being dismantled. The solutions can also be disruptive to local ecosystems (e.g. wind power) or be polluting with material if they are not recycled in a responsible way.

By doing a LCA (*life cycle assessment/analysis*) of each solution and it’s connected systems, we can better understand what are a more or less smart choices, and what the ecological footprints might be.

4. Introduction to Energy School

Sometimes we might see ourselves fitting in the role as teacher, but maybe we all need to identify ourselves as students as we learn how to create and live in a society less dependent on fossil-fuel?

The Energy School is a growing part of the platform where background-information and perspectives to the technical solutions can be found and communicated. Hopefully it will be a help to make us understand why some solutions or choises might be more smart than other. Here are some examples of topics that can be found on the platform:

Energy

> Introduction to energy
> Energy history - How has it been used?
> Thermal energy - How does heat & cold behave?
> Electricity - How is it produced & used?
> Renewable energy
> Energy storage
> Energy for the house - How to design and build?
> Current & future development

Sustainability

> Introduction to sustainability
> LCA - Life Cycle Assessment
> Waste - what is it and how can it be minimized?
> Closed Loop - Local systems with less waste
> Circular economy
> Resource sharing & Rural (local) development

Introduction to Energy

We all have different relationship to the term energy depending on our experiences from school, work or other aspects of life. When we speak about energy here we mean something that has an ability to do work and provide value to our ways of living. This might include heating for our houses, energy for cooking or electricity for running equipment and appliances. Maybe we can also include growing our food as it fuels us and covers some of our most essential needs?

When designing and building local renewable energy-solutions it is often very valuable to start with understanding what the needs are and what the local condition can provide, before deciding on what or how to build. In this way, the right amount of resources in terms and money, time and materials can be used, rather than making something that is too small to cover our needs, or too large.

Therefor the first advice, and maybe the most important when making off-grid solutions, is to spend time on observation, planning and preparation. By doing this, we might be able to minimize the waste of resources and spend them on things that brings more value.

Production & Storage

For renewable energy (especially off-grid systems) both the production and storage (batteries, biomass or hydrogen) part of the systems are equally important. Research and development is currently going into these areas and which will continue to increase the possibilities for us to live with these solutions with a comfortable level of living, all year around.

Energy efficiency and losses

There will always be losses in any energy system, which means that parts of the produced or stored energy will not be used for covering the actual needs. A system with high efficiency has small losses, and vice versa.

We aim to make solutions that have a high efficiency, but there will always be losses. Understanding where these losses appear and how they can be minimized is also one important aspect when we build systems to cover our needs, while minimizing waste and optimizing the use of resources.

Thermodynamics - How does heat behave?

One fundamental aspect of energy use, something that has been with us long before electricity, is heat (thermal energy). A technical term for how heat behaves is thermodynamics, and a basic understanding of this will likely help to increase our level of comfort. This might for example effect our choices in terms of how we build and design our houses and solutions in order to minimise losses and maximise comfort.

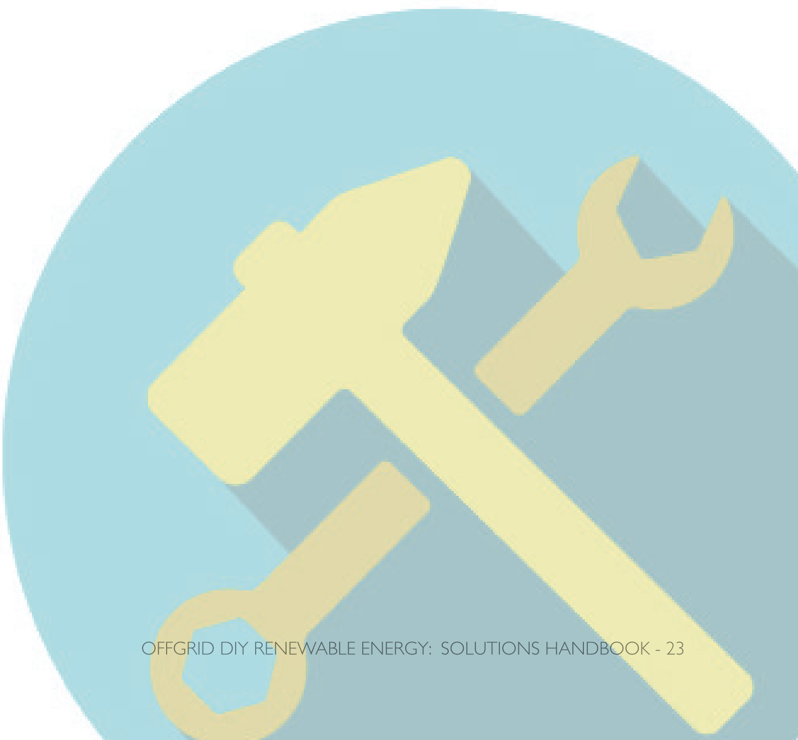
Thermodynamics shows us that thermal energy always moves from a warm material to colder, and that this happens in four ways; conduction, convection, radiation or phase change. Having an understanding of what all this means is a great base in order to understand how to live with energy and energy solutions in a smart and efficient way.

Find out about thermal dynamics, closed loops and more in the Energy School and through the solutions on the platform.

Welcome to the following examples of solutions here in the book!

5. Technical solutions - full descriptions of four examples

PV	Solar electricity & storage
Biomeiler	Water-based heat & compost
Rocket Stove	Heating & cooking
Wind Turbine model	Educational activity



CATEGORIES

SOLAR ELECTRICITY PRODUCTION & STORAGE

Off-grid photovoltaic system

Short intro

The goal is to build a low cost and simple off-grid photovoltaic (PV) system. PV refers to the solar energy that is used to generate electricity. Off-grid means that the system should operate without electrical grid connection. All the energy needed will be generated from the sun. The off-grid PV system consists of PV panels, power electronic converters and batteries. The solar panels capture the sun light and convert it into electricity, power electronic converters charge batteries and supply the load with that energy. The battery is needed to store excess energy for later usage.

Level of complexity

- Building and operating
  Medium (partially DIY, medium maintenance and operating complexity)

- Cost of the solution
  High (>500 EUR)

Skills, tools & materials

Skills

It is mandatory to have basic understanding of electricity, voltage, current and resistance. In order to calculate needed power and load one should know Ohms law. The basic theory is easy to learn from internet.

IMPORTANT! Understand your local regulations regarding electrical installations and always act in a safe manner!

Link *"Voltage, Current, Resistance, and Ohm's Law"*
https://learn.sparkfun.com/tutorials/voltage-current-resistan-ce-and-ohms-law/all,
Link *"Electricity Basics"*
https://www.altestore.com/howto/electricity-basics-a18/.

Tools

The following tools are needed for this project (Fig. 1, start from left): a multimeter (can measure DC voltage and current), wire cutters, pliers, different screwdrivers, carpenter knife (good for removing isolation from the cables), Soldering iron and tin solder wire.

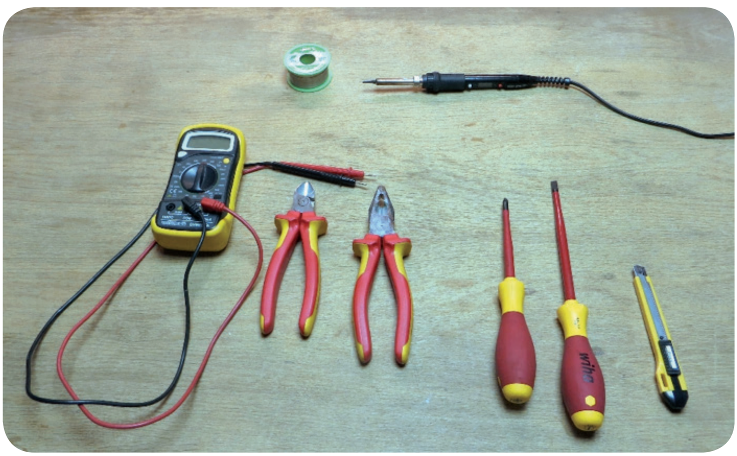


Fig. 1. Tools needed for building the solution

Fig. 2. Energy meter for measuring consumption and power

In the designing phase it is recommended to use some energy meter (Fig. 2) for accurate consumption measurements. However, the consumption can also be calculated as shown later. Thus, it is an optional device.

Materials used in the Current Project

The key component of the system is the PV panel.
In the current project two 275 W Chinese PV panels (CSUN275-60M - see Fig.3) were used.
The technical parameters are shown in Table 1.
Link https://napssolar.ee/, accessed 27.06.2020

Table 1. Technical data of the PV panel CSUN275-60M

Parameter	Value
Maximum Power Pmax	275 W
Open Circuit Voltage – Uoc	38.5 V
Short Circuit Current - Isc	9.13 A
Maximum Power Voltage - Umpp	31.3 V

Parameter	Value
Maximum Power Current - Impp	8.79 A
Module Efficiency	16.93
Price	112 €

To charge batteries with the PV power and to maximize the performance of the PV panels a charge controller with maximum power point tracking (MPPT) is needed.
In the current project the following charge controller Victron MPPT 150/35 (Fig.4) was used. The technical parameters are shown in Table 2.
Link ***"victron mppt 150/35"***
https://www.amazon.de/, accessed 27.06.2020

Table 2. Technical data of the charge controller Victron MPPT 150/35

Parameter	Value
Battery voltage	12 / 24 / 48V Auto Select
Rated charge current	35A
Nominal PV power	1000 W at 24 V
Max. PV current	40 A
Max. efficiency	98 %
Operating temperature	-30…+60 °C
Price	330 €

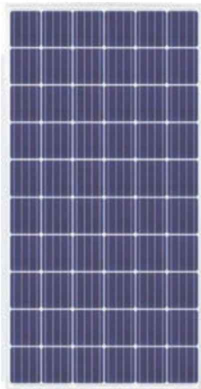


Fig. 3. 275 W Chinese PV Panel

Fig. 4. Victron MPPT 150/35

Fig. 5. Pure Sine Wave Power Inverter

Fig. 6. Deep cycle lead-acid batterie

An off-grid pure sine wave inverter is needed to convert battery voltage (DC) into a standardized grid voltage (AC). It is important to choose the pure sine wave (not just sine wave) inverter. This means that the output voltage will be pure sine wave 230 VAC that is accepted by all household devices.

Link *"Pure Sine Wave Power Inverter 24 V" (fig.5)*
https://www.aliexpress.com/

Table 3. Technical data of the pure sine wave solar inverter

Parameter	Value
Input voltage	24 Vdc
Output voltage	220 Vac
Max. power	4000 W
Output frequency	50 Hz
Low voltage protection	20 Vdc
Efficiency	>93 %
Price	130 €

To store excess solar energy and keep the system running also at night, batteries are needed. In this project deep cycle lead acid batteries (Fig.6) were chosen.

Table 4. Technical data of the battery

Parameter	Value
Voltage	12 V
Capacity C20 (corresponds to discharging time 20 h)	100 Ah
Energy capacity	1200 Wh
Type	Lead-Acid (deep cycle)
Charging current	10-30 % of the capacity
Price	100 €

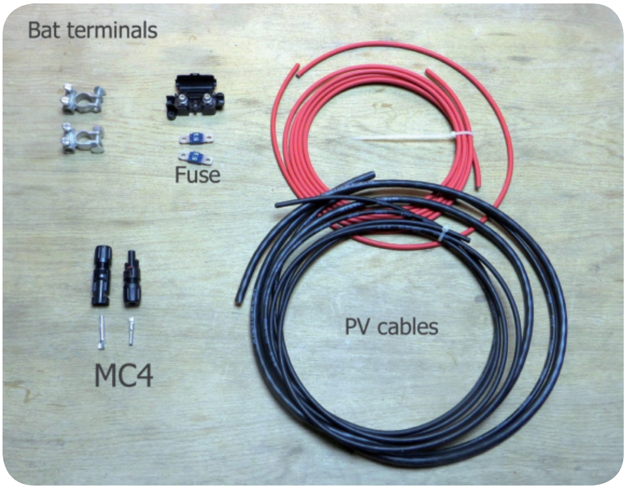


Fig. 7 : Cables, connectors and terminals

Fig. 7 shows small components and cables needed for the electric connections. The PV panels will be connected to the charge controller via special PV cables. The PV panels will be connected via MC4 connectors and batteries via battery terminals. The batteries must be connected through a fuse.

For this purpose, a simple car fuse with sufficient current can be used.

Conclusions and Errors to Avoid

Before starting to buy the components, learn the basics of electricity. Then do your calculations and find out how many panels and how powerful converters you need, the number and type of the batteries etc. First, design the system on paper and then start building it. If the system is well designed and analyzed on the paper, then the building will be an easy and quick task.
Before connecting batteries make sure you have fuses in place. Always connect first the charge controller with the batteries and only then with the PV panels. The charge controller is powered from the battery side and will not work properly with only PV panels connected. Check and doublecheck the polarity and allowed battery voltage of the charge controller. Do not swap plus and minus terminals. Read the manual of the charge controller for more detailed instructions before connecting it. It can be easily damaged if connected in a wrong manner. Note that there could be a small spark at the battery terminals at the moment of connection. This is normal and means that the output capacitors of the charge controller were charged.

The inverter is less sensitive converter than the charge controller. However, following steps must be followed when connecting it. First connect the batteries and only after that switch on the load. Note that there could be a small spark at the battery terminals at the moment of connection. This is normal and means that the input capacitors of the inverter where charged. Never connect two off-grid inverters in parallel or to the electric grid. It will destroy the inverter immediately.

Costs and Life Cycle Analysis

The total costs of the described PV system should be between 700 and 1300 € but depends on the chosen components. The most expensive and short living component of the system is the battery. The total costs of the presented system were around 900 €. It could be reduced by choosing cheaper charge controller.

The life expectancy of the system is limited by the battery life. Currently used lead-acid batteries can take less than 1000 charging/discharging cycles while Li-ion batteries reach >2000 cycles. This results in a life expectancy around 5-15 years.

The PV panels are required to have maximum degradation rate 1 % per year. This means that after 20 years 80 % of the nominal power could be achieved from the panel. However, today's panels, with better technology and improved manufacturing techniques have degradation rate less than 0.4 % per year. That means that a panel manufactured today should produce 92 % of its original power after 20 years. In general, the total life span of a PV panel today is around 30-40 years. Thus, the PV panels are the most durable components of the PV system.

Power electronic converters have life expectancy around 10-20 years after which the electrolytic capacitors inside must be replaced. Theoretically, this replacement can be done by anyone who knows how to solder.

Link ***"What Is the Lifespan of a Solar Pan",***
https://www.engineering.com/DesignerEdge/DesignerEdgeArticles/ArticleID/7475/What-Is-the-Lifespan-of-a-Solar-Panel.aspx, accessed 27.06.2020.

Footprint

PV-panels are made out of material that are mined and they have a rather large footprint and energy-usage when being produced They are also harmful for eco-systems if not discarded in a responsible way. Efficient recycling of PV-panels is becoming more common and available, and should be the natural choice once they are being discarded.
Most components and materials in the panels can be recycled and re-used when processed in specialised factories.

Batteries are also often made out of mined materials that have rather large footprint and are harmful to eco-systems if not recycled. There are possibilities to re-use batteries for storage that have had other usages before, and the development of new, more sustainable battery-technologies is constantly speeding up, as it is a central component of renewable energy systems.

Step by Step Guidelines for Building the Solution

1. Calculations and Design

Before starting with the building process, the off-grid PV system needs to be designed and planned properly. Although PV system can be built by yourself, most of the components (batteries, power electronic converters, etc.) must be purchased and building without a plan could lead to expensive mistakes. There are different strategies how to design a PV system but in the current project following steps were used:

1. Estimate local solar conditions
2. Load and consumption estimation
3. Storage selection
4. Inverter selection
5. PV power and voltage selection
6. Charge controller selection
7. Wires selection

2. Estimate Local Solar conditions

Before one can even think about building a PV system, it is important to know how much solar energy there is available on the site. For that purpose, EU has created an online photovoltaic geographical information system (PVGIS)

Link: Photovoltaic Geographical Information System'', https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#PVP
, accessed 28.06.2020.

It can be used free of charge. PVGIS can simulate both grid connected and off-grid systems. To find out optimum PV panel angle at your location, first run grid connected simulation.
Fill out following fields:

1. Your address,
2. Installed peak PV power – Use preliminary estimation how many panels you plan to install.
3. Estimated system losses – usually between 10-20 %.
4. Mounting position – either free-standing (on the ground) or building-integrated (on the roof or wall).
5. Angle of the panels – if you do not know the optimum value, leave it empty and click the checkbox on the right (Optimize slope). PVGIS then calculates the optimal angle for your location.

Click *visualize results* and see the data (Simulation outputs). PVGIS gives you optimum slope angle, yearly PV energy production and also shows the monthly energy output graphically. You can run the PVGIS off-grid simulation later when you have calculated your exact PV system parameters i.e. size of battery, power level and number of panels. PVGIS off-gird simulation shows you how much solar energy your system can capture and how much will be lost. Now you can fine tune your off-grid PV system by increasing the energy storage or reducing the number of PV panels.

3. Load and consumption estimation

The second step in the case of any PV system is the estimation of load and consumption. By knowing the load, the needed power and number of PV panels, the required energy becomes defined. The easiest method for load estimation is to conduct some measurements with a simple energy meter (Fig. 2). Connect all devices which you plan to run off-grid to the energy meter and measure the needed energy and power levels over some period of time (1-5 days).

If you have no electricity or no energy meter you can also calculate the needed electric power. First, create a list of devices you want to operate. Usually all household devices have a data plate with electrical parameters. If you cannot find it then check out the list of typical household appliances and their typical power ratings (in Watts) in internet.

Link *"Power Ratings (Typical) for Common Appliances"*
https://www.altestore.com/howto/power-ratings-typical-for-common-appliances-a21/, accessed 28.06.2020.

You can use this information to help you estimate the total amount of Watt-Hours that your alternative energy system needs to supply on an average day. The consumed energy over a time period can be calculated from the power as follows:
$E = P \times t$,
where E is the energy, P is the electric power of the load, t is the operation time of the load.

In the current project the load consisted of a water pump and a refrigerator. If the 300 W pump works 3.7 h per day it consumes about 1100 Wh energy. The 200 W refrigerator is expected to work about 4.5 hours/day and consume 900 Wh of energy. The total energy needed is 2000 Wh/day. The maximum power of the system is 500 W.

4. Storage Selection

As a rule, the bigger the better. In a off-grid PV system the size of the storage is strongly correlated with the living comfortability. Smaller storage simply means less energy at night or at cloudy days. However, the energy storage (battery) is also the most expensive component in the system. Thus, the selection of the size will be a trade of between price and living comfortability.

First step would be to select right storage technology. In general, one should decide between Lithium and lead-acid battery. Lead-acid is cheaper but also has much lower efficiency and life cycle. Lithium has two times higher initial costs but lasts longer and works with greater efficiency. A good guide about technological differences and battery selection can be found from the internet.

Link *"Batteries: Lithium-ion vs AGM"*
https://www.victronenergy.com/blog/2015/03/30/batteries-lithium-ion-vs-agm/, accessed 28.06.2020

Second step is to select suitable voltage. Higher voltage is better since it results in lower current and in cables with smaller diameter. Moreover, many of the charge controllers accept multiple battery voltages. With twice higher voltage the same charge controller can process twice higher power. In practice, the chosen voltage depends on the system power as follows:

power < 800 W, battery voltage 12 V
power < 2000 W, battery voltage 24 V
power < 6000 W, battery voltage 48 V

Link *"How to connect your batteries to make up a 24V or 48V system"*
https://www.newenergyco-op.co.uk/blog/how-to-connect-your-batteries-to-make-up-a-24v-or-48v-system.html, accessed 28.06.2020.

Multiple batteries can be connected in series to get higher voltage (recommended) but they can be also connected in parallel to get more current. Note that the energy content of the battery pack is not depending on the connection type. It is only defined by the chemistry inside the batteries. The energy content E of the battery can be calculated as:

$E = U_{bat} \times C_{20,}$

where U_{bat} is the battery nominal voltage, C_{20} is the rated capacity for 20 h discharge of the battery given in Ah.

In the current project the storage should cover one day energy consumption 2000 Wh (see chapter Load and consumption estimation). Due to price limitation lead-acid batteries were selected. Two 100 Ah, 12 V deep cycle batteries were connected in series resulting in total energy content of 2400 Wh and voltage 24 V. This will cover the daily energy need.

5. Inverter Selection

Inverter is a power electronic device which converts battery dc voltage into sinusoidal ac voltage. The inverter will be chosen according to load power and battery voltage. The inverter must always have some power reserve. How big power reserve is needed depends on the type of load. A rule of thumb is to choose the inverter with 2-3 times bigger power rating than required by the load.

In the current project the maximum expected power of the load was 500 W (see chapter Load and consumption estimation). Thus, the minimum requirement for the inverter is 1000 W. In the current project an inverter 4000 W was selected.

6. PV power and voltage selection

The PV panel is a nonlinear energy source that has neither fixed voltage nor current. PV panel is insensitive against short circuit and open circuit. In both cases it delivers no power.

The point of maximum power is somewhere between open

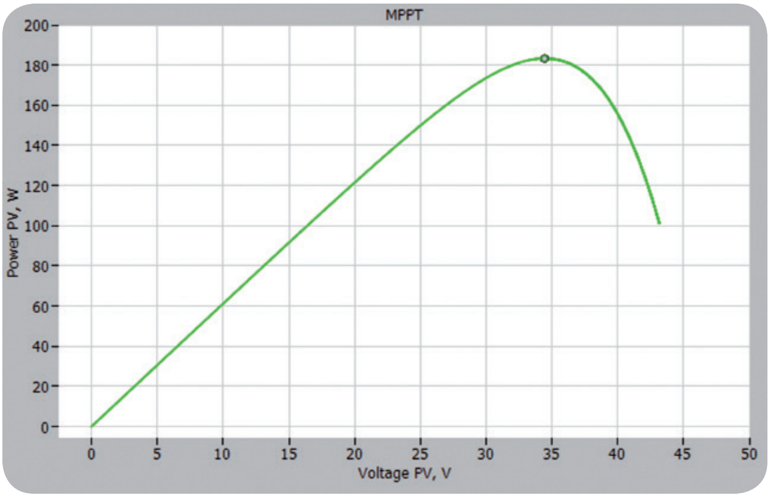


Fig. 8. Power vs. PV voltage graph

circuit (no load) and short circuit (overload) point, as shown in Fig. 8. This so-called maximum power point (MPP) must be continuously tracked by the charge controller.

The number of PV panels depends on the electric load. The peak PV power should reach at least the load level e.g. 1 kW load demands at least 1 kWp of PV power. However, the PV production heavily depends on the weather and is drastically reduced with clouds. Thus, it is common to install 10-20 % more PV power than required by the load. More PV panels compensate for bad weather. Note that the PV voltage in MPP should be 7-10 V higher than the battery voltage. This is due to the fact that most of charge controllers on the market are step-down converters i.e. they cannot increase the voltage. If the MPP voltage (V_{mpp}) is lower than the battery voltage, then the charge controller can never extract maximum power from the PV panel.

In the current project maximum load power is 500 W (see chapter Load and consumption estimation). Two 275 Wp panels were selected.

The minimum required MPP voltage is $U_{bat}+10 = 34$ V. The U_{mpp} of the PV panel CSUN275-60M is 31.3 V (Table 1), which is lower than the minimum requirement. Thus, the panels had to be connected in series, which resulted in new MPP voltage 31.3x2 = 62.6 V. As a conclusion, in the current case the PV panels could not be connected in parallel due to the too low U_{mpp}.

7. Charge Controller Selection

There are two types of charge controllers: MPPT controller and PWM controller. PWM charge controller is a low-cost solution that suits best for small PV systems with moderate to high temperatures (45-75 °C). In northern countries where solar irradiance fluctuates and the average temperatures are lower, MPPT controller is a better solution.

Link *White paper: "Which solar charge controller: PWM or MPPT?",* https://www.victronenergy.com/upload/documents/White-paper-Which-solar-charge-controller-PWM-or-MPPT.pdf, accessed 28.06.2020.

Next criteria to consider are: power of PV panels, open circuit voltage of PV panels (U_{oc}), battery voltage and charging current. In the current project PV power was 550 W, U_{oc} = 2x38.5=77 V (Table 1), U_{bat} = 24 V, max charging current P_{pv}/U_{bat}=550/24=23 A. According to this data a Victron energy MPPT controller was selected (Table 2). The Victron MPPT 150/35 charge controller supports PV voltage up to 150 V and battery charging current up to 35 A.

Building the Solution

1. Building the frame

The frame can be built from timber, as shown in Fig. 9. The dimensions and construction drawings are shown below .

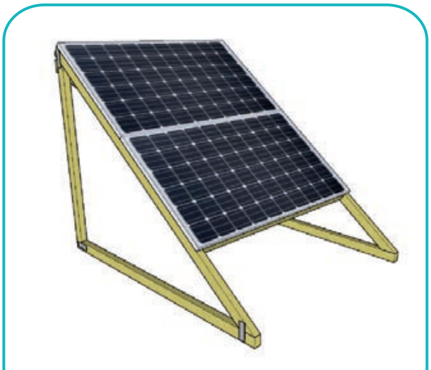
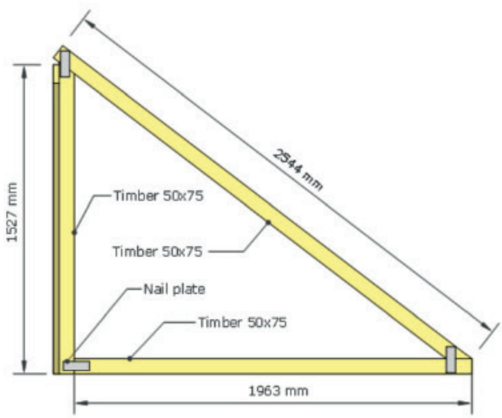
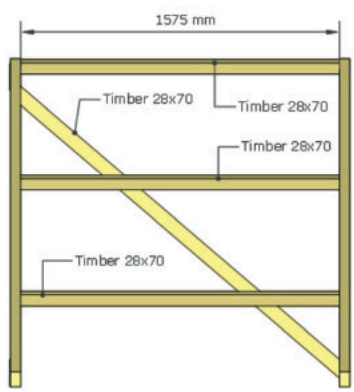


Fig. 9. Timber frame for PV panels

The list of timber and measures:

- 50x75x2400 mm, 2 pieces;
- 50x75x1500 mm, 2 pieces;
- 50x75x1800 mm, 2 pieces;
- 28x70x1300 mm, 3 pieces;
- 22x150x1300 mm, 3 pieces.





Electrical connections

Electrical principle diagram is shown in Fig. 10. The system consists of two PV panels, the charge controller, two lead-acid batteries in series connection and inverter. Electric loads will be connected directly with the inverter.

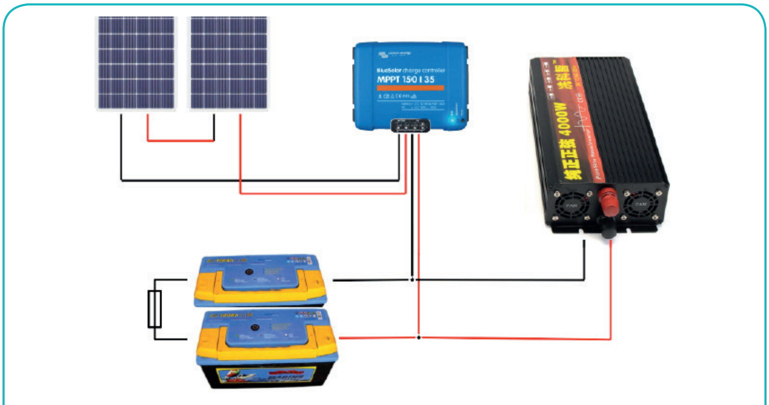


Figure 10: Electrical principle diagram of the prototype

Fig. 11. A complete off-grid photovoltaic system

Videos

https://www.youtube.com/playlist?list=PLk7r5FyAZw9mo-KacHwVa8mIEwRr-spznP

Author of the content

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CATEGORIES

WATER-BASED HEATING

COMPOST SOIL-IMPROVEMENT

Biomeiler/Jean Pain

Compost with heat exchanger

Short intro

Biomeiler is a heat compost which contains biomass mixtures with wood chips making up for at least 70% (70-80%) and the rest of manure (max 20-30%). Water is added to biomass continuously during assembly to attain desirable moisture content needed for the breaking down of the biomass. The biomeiler can heat up to between 50-60°C and this temperature is attainable within 2-7 days, though atmospheric conditions play a role and the start-up time may exceed the stipulated time. The heat produced is collected by water circulating in the plastic pipes that are laid inside the biomeiler during construction.

A biomeiler of about 10 m3 in size produces 1 kWh heat. But it depends for example on what kind of manure you use. Biomeiler's working time is between 6 to 24 months after which the pile reduces by about 40%.The shift in the compost material should be taken into consideration when setting up the pipes.

Level of complexity

- **Building and operating**
  Low (partially DIY, medium maintenance and operating complexity
- **Cost**
  High (requires special skills to build, complex maintenance and operating, cost >500 EUR)

Building a biomeiler needs some tractor work and a few people. Material costs are high, because wood chips are expensive >500€. Pipes, wire mesh and other materials also need to be available, however they are reusable again and again. However the case presented here from Meteoria cost between 5000-6000€ for the implementation of the current working system from scratch shown in Chapter 8 of this report.The solution is a state-of-the-art giving online live data of the temperature sensors in the compost.

More details of the solution and technical description

A biomeiler is a large compost that produces heat, collected by 32mm diameter plastic pipe with circulating water.The warm water can be transported to buildings or the heat can be extracted with a heat exchanger. The compost contains manure (max 20-30%), woodchips (70-80%) and it must be wet.

Overview of a biomeiler-system

Skills, tools & materials

To build a biomeiler you need a tractor, some hand-tools (shovels) and at least a couple of people. Other needs and materials are:

- FRESH wood chips
- plastic to cover the bottom
- drainage pipe in the bottom to remove excess water
- antibiotics free manure, 20-30% of the total volume
- water to make biomeiler moist
- 32mm plastic pipes ca. 600 meters (depending on the total volume)
- iron net or concrete reinforcement and wire mesh for walls, to get round shape

Other preconditions and/or requirements

Check your local regulations on what is required for you to build a biomeiler.

Results, learnings and errors to avoid

Wood chips must be fresh (not more than 3 weeks from cutting) and compost must be wet enough. Take care of irrigation during building

Cost and life cycle analysis

Over its life cycle the biomeiler produces heat ca. 800-1000 kWh/m^3 depending on woodchips. Wood chips price is the same when we are burning and composting. Biomeiler working time is 6-24 months.

Step by step guidelines for building the solution

1. Build the walls to round shape and lay plastic on the bottom. (in the picture straw bales are used for walls instead of wire mesh)

2. Add to bottom culvert pipes that collect excess water away

3. Fill the biomeiler with mixture woodchips and manure and add plastic pipe in spirals in 2-3 layers to compost during building. Make sure that both ends of the pipe are accessible from the outside of the biomeiler.

4. Connect heating line. Insulated with straw-bales. Add circulation pump in a warm, insulated place and connect heated water to where it should be used.

5. The ready compost is good fertilized soil for plants, for example greenhouses, and other material you are able to use for the next biomeiler.

Local Prototype(s)

- Vaasa Meteoria Biomeiler

The biomeiler in Meteoria Vaasa was completed in December 2019 and heat energy extraction started in that same month. The heat collected is used for the heating up of the conference room (barn). Shown in the figure 1 below is the schematic drawing of the biomeiler heat compost energy system, showing the different elements and layout of the systems.

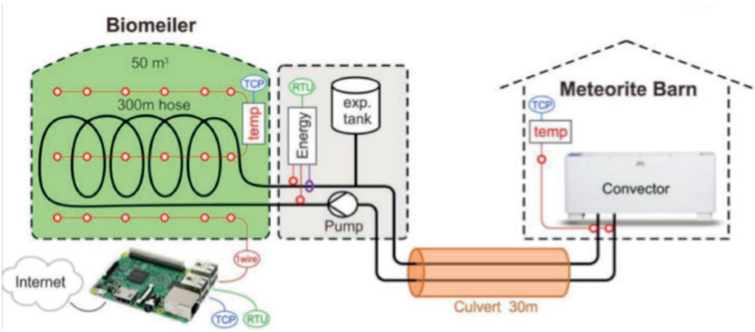

Fig.1: Schematic of the biomeiler energy system and application - Vaasa, Söderfjärden

Fig.2 :The completed biomeiler

Construction and Dimensions of Meteoria-biomeiler

The biomeiler has a capacity volume for biomass of $50m^3$ as can be seen from the schematic figure above. The biomass used in this biomeiler is horse manure due to its slow decomposition rate consisting of 20% of the total biomass. The rest of the material used is wood chips (80%). In the initial stage, about 10 m^3 of water was added, some added to the pile and some mixed with the biomass before adding the biomass to the biomeiler. The local residents assisted in the construction of the biomeiler providing free manpower, horse manure and some other resources as can be seen in figure 3 below.

Figure 3: Locals assist in the construction of the biomeiler, first layer of water circulation coil laid:

As can be seen, no plastic material was added to the borders of the biomeiler, this was to allow for aeration and it cannot be proven that omitting the plastic material has a negative impact as will be shown in the coming chapter. The concrete reinforcement wire is for holding the structure in place and the (chicken)wire mesh inside is for holding the biomass. The temperature sensors were placed on various points in between the tube spaces.

The biomeiler has a 300 m hose running through it coiled in 100 m lengths in three layers (the bottom, middle and top) of the biomeiler to spread the collection of the heat. The temperature sensors are installed at each layer on different positions, there are 24 temperature sensors in this prototype biomeiler alone and they are connected to an online data collecting tool via Raspberry Pi.

The biomeler was loaded to the top marking 50 m^3 volume of biomass (Fig.4)

Figure 4: Filling up completed, the 50 m3 mark and the early stages of putting insulation.

The biomeiler is insulated with straw bales (Fig.5) to reduce heat losses to the environment caused by the temperature differences between the biomeiler and surrounding environment.

Figure 5: Hay insulation around the biomeiler

Heat Extraction

Heat extraction started in the mid of December 2019 and the figure below shows the timeline of production by the biomeiler and steps taken to try and increase heat generation in the compost.

The temperatures shown in the graph (Fig.6) are an average from various temperature sensors in three different positions of the biomeiler. The blue line indicates the temperature readings from the sensors located in the middle of the composts, the orange line represents sensors in between the middle and the edge of the biomeiler and the grey line is for the sensors on the edge of the compost. The various temperature outputs from the compost can be seen and the period of these outputs ranging from the middle of December 2019 to the middle of March 2020.

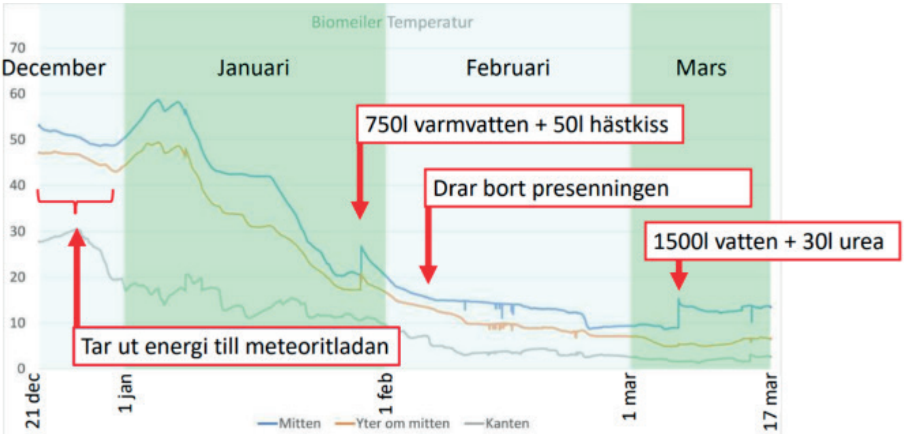

Figure 6: Timeline for heat extraction & remedy steps

The graph above also shows the timeline of activities that has occurred during the recorded period. In order to extract more heat from the compost, 750 litres of warm water and 50 litres of horse urine was added to the compost at the end of January, to boost the nitrogen level in the compost and also maintain the moisture level.

The tarpaulin (outer insulation made of straw) was removed in February to see effect on temperature sensors and check for the moisture content of the biomass in the compost. In the beginning of March 2020, 1500 litres of water and 30 litres of urea was added to the compost. Not shown in the graph, the end of March, about 1 m^3 mixture of cow dung and urine were added. The mixture was added to the compost by creating a crater on top of the compost and let the mixture seep down gradually. No further data has been in the period from the beginning of April due to some problems in the weather station.

Observations and Conclusion on Heat Extraction Results

As seen from the graph on the Figure 6, there is a clear drop of heat in the biomeiler from the mid of January from a staggering ~60˚C to below 30˚C, but still a significant difference in locations of sensors. Given that horse manure decomposes very slowly, it still raises a question of how the decomposition occurred so fast. It was also observed that the outer sensors showed much lower temperatures throughout, an indication that there was air flow from the surrounding environment. It is also an indication that this is an aerobic process and was getting oxygen from the surroundings. Another indicator of the presence of oxygen and moisture was when the tarpaulin was removed, the biomass was still moist and all temperature sensors showed a tiny drop in temperature.

Nitrogen is an important element in this process and it is an element that is present in urine and excretion matter. After the addition of horse urine, the temperatures from the middle and intermediate sensors showed an increase in temperature of about 5 ˚C but the temperatures dropped after removing the tarpaulin. When next urea and water was added, only the middle sensors showed an increase in temperature. One explanation for this is that the water and nutrients do not evenly spread out in the compost, it takes the easiest way down.

Not shown on the graph was when cow excreta mixture was added, on the occasions the readings were observed, the temperature sensors showed temperature readings of above 30 ˚C. However, it was the same observation as in previous steps that it is difficult to evenly distribute the extra nutrients in the biomeiler once it is compiled. Adding nutrients to a compost at a later stage is a challenge as there is no even distribution of the extra nutrients. This makes having a correct biomass composition from the initial stage important.

Further observing the biomeiler, it was noted that it had been transitioning into hibernation from the time the temperatures start dropping to below 20°C as can be seen on Figure 6. The temperature started rising gradually towards the end of May 2020. Looking at the weather patterns in Finland, the period the biomeiler was in hibernation falls in the cold season for Finland, leading to a conclusion that the insulation around it did not help much and could have fallen below the optimal operating temperature for the enzymes. A clear conclusion can be researched by observing the biomeiler for a longer time and observing the change in temperatures during different times of the year.

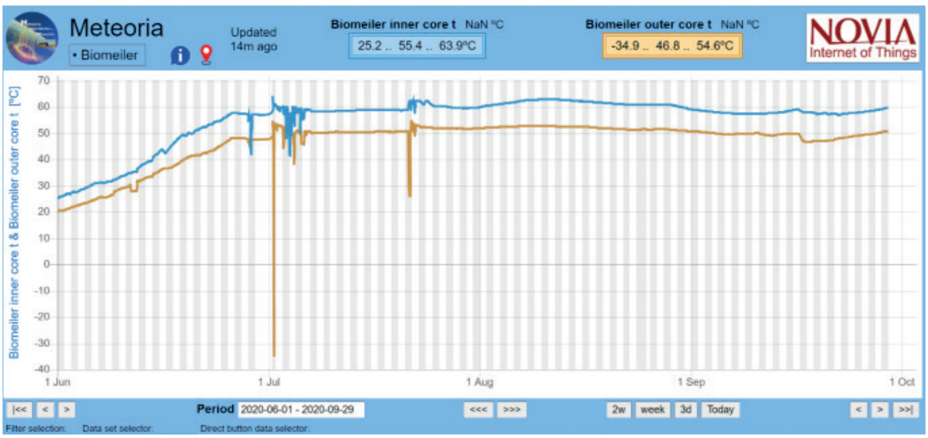

Figure 7: Biomeiler heat production for the period June to September 2020.

From Figure 7 above, it can be seen that the biomeiler has reached the peak values of temperature and has remained stable to time of writing this (September 2020). The biomeiler's live data as well as back data can be followed and accessed through the website http://iot.novia.fi/data/meteoria_biomeiler.html

Basing a conclusion on this biomeiler, further observations should be made to concretely connect the impact of atmospheric conditions on a biomeiler. The earlier conclusion reached that since the difference in particle size between horse manure and wood chips is wide, some of the horse manure ran out with water and the wood chips were too big to start breaking down in such a short time frame so that they compensate for the depletion in the horse manure is now hard to fully support. Other questions are if the extra nitrogen added to biomeiler was necessary in the first place and on one hand if this could be a solution to sustain biomeilers in very cold regions during the cold season.

Context of the prototype

During Off Grid DIY project two prototypes were built in Finland: One in Seppälä Agricultural College in Kajaani, one in Meteoria, Vaasa.

These workshops are based on an original prototype which was a Leader project, where biomeiler construction manuals in Finnish were made.

People, community, institution and/or organisation operating the prototype

Meteoria, Vaasa (TBD), Novia University of Applied Sciences
Shiva Sharma, Project Leader (shiva.sharma@novia.fi)
Hans Linden, Lab Engineer/Project Researcher (hans.linden@novia.fi) & Cynthia Söderbacka, Project Researcher (cynthia.soderbacka@novia.fi)

Videos

https://www.youtube.com/watch?v=jPO0CuurUZc

The video in English:
https://www.youtube.com/watch?v=gW1Rb33Hjug

Experts involved
Energy expert Jukka Kontulainen

Contact information for more information about the solution in the country of presence
ProAgria Länsi-Suomi ry/ Energy expert Jukka Kontulainen
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References
https://lansi-suomi.proagria.fi/sites/default/files/attachment/bio-meiler_hanke_esite_a4_032018w.pdf

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CATEGORIES

COOKING
THERMAL/HEATING

Rocket Stove

+ oven, mass and water heater

Level of complexity & cost

- **Building and operating**
  Medium (does not require special skills to build, low levels of maintenance)

- **Cost of the solution (operating and building)**
  Low - medium (<50-200 EUR for building)

Short intro

The rocket technology is about producing high temperature heat (700-1100°C) with a clean burn (low emissions of smoke and greenhouse gases) while using minimal amounts of fuel. It's a thermal energy solution that is cheap and quite easy to build but can be applied to cover many different needs when and where heat is wanted. Applications can be as a stove, an oven, a space-heater or a water-heater (connected to an accumulator tank or radiator system). The effectiveness comes from understanding thermodynamics and using specific dimensions and proportions when building the rocket.

One of the most simple ways of using the heat from the rocket is as a stove, placing a pot or pan directly on top of the rocket in order to cook food, boil water or other similar usages. The other, slightly more complex modification of the rocket can be found on the platform, with the rocket mass heater perhaps being the most effective usage of the rocket.

General idea of the solution

> having a fuel-efficient source of heat (good for costs, time and environment)
> being able to achieve high temperatures
> can use fuel (biomass) that doesn't require a lot of processing (branches, sticks, pinecones)
> having a clean burn with few non-combusted gases (good for health and environment)
> that the technology can possibly be built with locally sourced materials and often quite cost efficiently.

How it works

By building the rocket while using specific measurements and dimensions of the system, the rocket allows for 2 separate combustions in the same system, which results in higher temperatures, cleaner exhaust and less fuel. In the first combustion (A), the gases are released from the fuel (C) and burned at 300 - 600°C. The non-combusted gases left from the first combustion in the burn-chamber get a chance to reach high enough temperatures (through friction in a limited, insulated space) in order for a second combustion to occur inside the heat-riser (B), before the heat/energy is being released and used at 700 - 1100 °C. By insulating the system and using the heat at the exhaust, less energy is "wasted" than in most traditional biomass stoves.

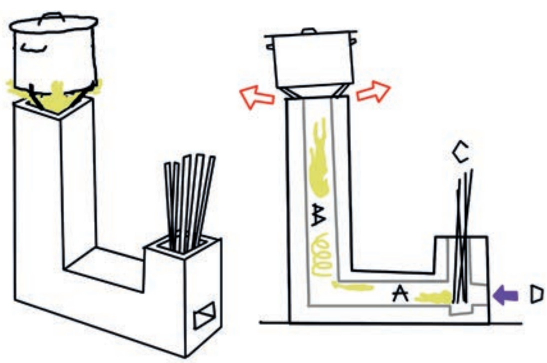


Fig. 1: Illustration showing the basic functionality of the rocket

Skills, tools & materials

Skills

Building a rocket-stove does not really require any special skills or building experience, even though it is always helpful to have some experiences when building (e.g. working with natural materials, bricks, metal or making molds for casting).

Tools

It is good to have a basic setup of hand tools when starting a build of a rocket. Depending on which solution you choose, and with which combination of materials, different tools may be needed.

Here is an example for building one of the more common solutions, using fire bricks and clay-straw insulation:

- A diamond cutting-disc will be good to have if cutting brick, used with an angle-grinder. Make sure proper safety equipment is used, including goggles and mask.
- A metal cutting disc will be needed.
- Mortar equipment, (e.g trowel).
- Large container/bucket for the clay/sand/water mixture
- A tarp for mixing the clay/sand/water with straw for insulating layer
- A measuring tape and a leveler

Materials

A rocket-stove can be built using different materials and different combinations of them. The important properties of these are that they can withstand high heat without deforming or degrading (refractory), and that they have enough insulating properties where needed. Trapped air (<4mm pockets) will ensure good insulation without convection in the material. Here are some examples of materials and how they can be combined:

- Fire bricks (for structure) and clay-straw mixture (for insulation)
- Leca-blocks with clay-sand/refractory mortel (for structure and insulation)
- Leca balls in a clay-sand mixture (for structure and insulation) - Molded solution
- Stainless steel pipes (for structure) and thermal-resistant insulation.
- Refractory clay + straw (for structure) and clay-straw mixture (for insulation)

If wanting to build other rocket solutions than a stove, there are also other materials involved, specific to the solution. More information on this will be found on the platform where other rocket solutions are presented.

If using metal, use stainless steel.

If and when using metal inside the rocket, or as a stove-plate, it is important to use a heat-resistant steel once the design is done (not prototype stage). This often mean that stainless steel (SS) is needed in order to ensure a long lifetime of the installation, even though SS is often quite expensive, more challenging to process (f.ex. welding or cutting) and can be difficult to find in scrap-yards. Optional metal to SS is 3CR12, which has similar properties but often half the price.

If not using stainless steel in the system, an effect called spalling will likely occur. This is a type of rusting that breaks down the metal in a rather short period of time and happens when the steel is exposed to high temperatures (>500°C) in an oxygen-rich and carbon-low environment. Carbon is then extracted from the metal, causing it to flake and dissolve. If the metal is not insulated, this might decrease the effect of spalling as convection is cooling, but also means lost heat in the rocket. As any metal (mined material) should be viewed as a precious resource, we should perhaps try to not use designs where the metals are broken down and causing pollution, indicating that it is a less smart solution. This would also result in more work and repairs during the lifetime of the rocket.

Cost and life cycle analysis

The cost and time needed for building a rocket varies a lot depending on chosen materials and the price of materials at the location. Fire bricks are for example much cheaper in some areas than others, making that a more or less costly option for some (if using clay mortar, they can however be reused if wanted). The price of a rocket-stove would normally be between 50-200€. The cost of operating the rockets depends on the sourcing of fuels, which is described on the following pages.

As has been described earlier, the rocket has both very low emissions and high fuel efficiency compared to most other biomass furnaces, stoves or kilns. The footprint related to operating the rocket is much connected to what kind of fuel is being used and if they are a part of a circular economy (otherwise considered to be ''waste'').

The footprint related to the building-phase of the rocket depends on which materials are being used. Fire bricks, Leca blocks or Leca balls are all processed at high temperatures and transported, resulting in a footprint. Any metal used also has a considerable footprint, less so if the material is recycled locally or reused.

Using a high amounts of locally sourced ''natural'' materials (clay, sand and straw) will result in the smallest footprint in the building phase.

Energy capacity and efficiency

If building the rocket in a correct way, so that a secondary combustion occurs, the temperatures in the top of the rocket can reach temperatures of 700-1100°C. This depends on the height of the heat-riser, the quality and dryness of the fuel, amount of the fuel and burn-time.

The rockets are to be considered an energy-efficient solution, especially when taken in consideration that little energy and time is needed for gathering or processing the fuels (branches, sticks, pinecones). Experiences show that a rocket stove uses 20-40% less fuel than other stoves for cooking.

Fig. 2: Image of a rocket-stove during installation, made out of fire-bricks and clay-straw insulation.

Fuels

The rocket works best with fuels that have a lot of contact area f.ex. branches, sticks, pinecones or pellets, rather than large pieces of traditional firewood. Fuels from leafy trees tend to result in a burn with less smoke or soot than fuel from evergreens, as these often have high resin-content. This might not have a big difference when using a rocket-stove, but it might create unwanted build-up in a rocket-mass-heater, or blacken the food in a rocket-oven.

Branches from undergrowth in forests are often just collected and burned in large piles. These could instead be collected and dried as fuel for rockets. The laws and rules that regulate how biomass can be collected in forests might differ between countries, so understand what is allowed in your area, or communicate with local landowners, if you don't have your own property to gather fuel from.

Pellets can be a good fuel for rockets as they have a large surface area and can easily be handled. There are also ways to create more or less automatic filling systems for pellets, either by gravity or electrical controllers (f.ex. using a screw or hopper). An automatic filler is a more complex solution but might be wanted for a rocket-mass-heater or a rocket-water-heater. The important detail is that the burn-chamber doesn't get clogged up, reducing the airflow from the air-intake too much. If sawdust or other waste materials are used from local industries when making the woodchips, perhaps even using a smaller pellets-machine, it fits into a circular economy and can be considered quite smart, even though there is some processing involved.

It is, as always when burning biomass, important that the fuel is dry, as it otherwise decreases the heat in the system through phase-shift of the water and causes a more unclean burn with more emissions and less effect.

Safety

Because the rockets are burning biomass, it can be a health-hazard to operate the stoves indoors or in spaces that are not well ventilated or without specific solutions for the exhaust gases. This may limit the usage of the rocket as a stove in cold seasons as there's a need to have a well ventilated space, for example in an outdoor kitchen. The compounds that can remain in the exhaust gases are otherwise harmful to breathe in, or reduce the amount of oxygen in the room. Examples of these are f.ex methane, CO, CO2, even though most of the hydrogen and methane will likely combust when the rocket is heated up, after 5-10 minutes from start. At this point there shouldn't be any smoke or soot coming from the rocket, which often are the factors that cause most respiratory problems.

CAUTION! Always use a CO monitor when having a combustion indoors or in areas with limited ventilation!

Regulations and legal aspects

Local regulations may apply that restrict where and how the rockets can be used and it's good to check with local authorities in order to find out what works in your area. As the rocket stove does not have any chimney if placed outside, there may be less regulation regarding permits, as long as they are not placed indoors.
Other rocket solutions suggested for space heating, such as the rocket mass heater, are designed for indoor spaces, but may have specific regulation and demanding pressure testing before being approved for usage. This is extra relevant as the solution is built on site, thus lacking any CE marking that often otherwise is required. Check with your local certification-provider for stoves and chimneys for relevant information.

Description of the solution

The name Rocket has been given as the stove, when working correctly, sounds similar to a rocket as the air is being pulled and pushed through the system with high speed. If it doesn't sound like a "rocket", something is probably wrong.

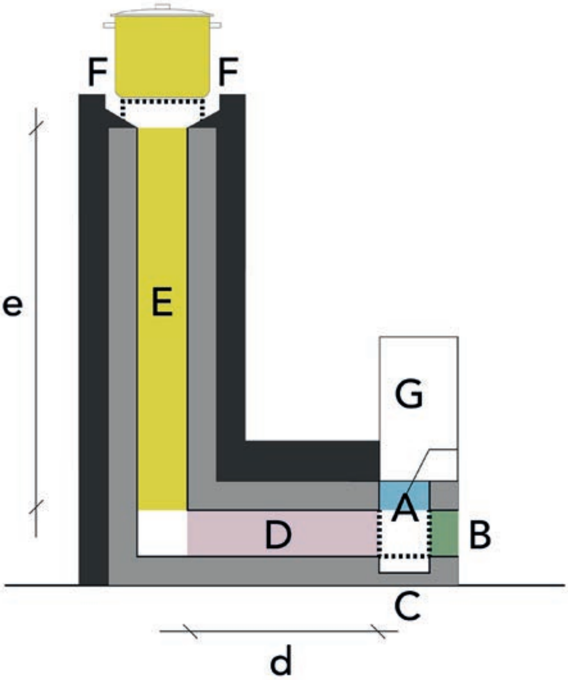
Spotting a "wrong" rocket

The rocket-sound is not enough though in order to determine if the dimensions are optimal and the rocket has all the properties that we seek. There are many descriptions of solutions posted online or in other places that may sound like a rocket, but are not following the "rocket rules". This often results in a lower maximum temperature, more wasted energy and more emissions. If f.ex. the heat riser seems very low, or the stove is made of uninsulated materials, we might think that the laws of physics are not fully respected and that optimal conditions are not met. These solutions might still be quite good, depending on conditions and needs, but it's not the same kind of rocket that we are trying to make here.

The important dimensions of a rocket

The size of each stove is determined by the cross sectional area of its heat-riser. A size that is often used for large rockets is a round shape with a 20 cm diameter opening (8 inch), which equals 17.7x17.7 cm for a squared shape (314 cm^2).

If wanting a stove with less effect then the cross sectional area should be reduced, which also results in less height which could otherwise be a limiting factor. Adjustments might have to be made in order to create a comfortable working height when cooking with the stove (standard height for a workable surface is approx 90 cm). This can be achieved either by burying the foundation of the stove in relation to the floor, or elevating the floor/ground.



A: Feed tube
B: Additional air intake and cleaning hatch
C: Ash pit under fuel
D: Burn chamber d: length < e/2
E: Heat riser e: height
F: Exhaust outlet and stove surface
G: Possible cover or storage/guide for fuels

The grey layer is the internal building material and the darker layer is the insulation. These might be the same if using for example leca-blocks, adding both structure and insulation

The dimensions shown in the illustration are the largest height-to-cross section area ratio. If the rocket has a 314 cm^2 area, these proportions results in the height of the cooking surface being 160 cm, which of course is too much without adjustments of the base and smaller dimensions might be more suitable.

Feed tube & air intake (A)

The feed tube is where the fuel (branches, twigs, pinecones, pellets etc) are inserted. The solution shown here is called a J-tube, which means that there is less need of pushing the fuel into the burn chamber as they burn and you can instead rely on gravity as the fuels are inserted from the top. If irregular branches are used, they might hook onto each other, and it is advised to have as straight pieces of fuel as possible. The height of the feed tube should also be kept low in order to ensure a good draft, not creating a chimney for heat to build up. Extra equipment (G) could be added on top of the fuel tube in order to stop air and flames from moving upwards and/or to support longer pieces of fuel (or a system for pellets).

Extra Air intake (B)

As the feed tube can get filled up, thus reducing the flow of air into the rocket, an extra air intake might be needed. This opening can also be very useful for cleaning out the burn chamber from ashes and other build-up. This extra intake might also be very much needed for a rocket that is placed indoors, as external heat then can be directed to the rocket through a channel, instead of it being taken from the inside, sucking cold air into the building.

The total size of the air-intake is important to the rocket and it's often needed to experiment with it by covering the intakes with for example cut bricks. One ratio used between total intake and heat-riser area is 1:1.5, meaning that the intake area (including an open feed tube) is about 65% of the heat riser, to minimise cooling effects from the air.

Ash pit (C)

By making a compartment at the bottom of the feed tube, separated by a removable metal mesh, most of the ashes and uncombusted material can gather there for easier cleaning.

Burn chamber - Cross area, shape and length (D and d)

Some builders mean that the length of the burn chamber is optimal when it's half the length of the height of the heat riser, but experiences show that this might result in too much heat loss. It is here that the heat starts to build up so it is important that the section is well insulated, minimizing losses before the heat riser. From our experiences, the length of the burn chamber should be less than half the height of the riser.

It is important that the cross sectional area of the burn chamber is the smallest of the entire system in order to have the right draft. A common design is also for the burn chamber to have the shape of a horizontal rectangle, rather than a square or a vertical rectangle (less height than width).

Heat riser (E)

The heat riser is one of the most important parts of the system, and different shapes of it will have different results on the flow of gases and achieved temperatures. A round shape is considered to be most efficient, followed by an octagon shape and then a square. Depending on the used materials, these shapes can be achieved with more or less complexity. If e.g using fire-bricks or Leca-blocks, a square shape might feel more attractive to build, even though other shapes can be made with some additional effort). If instead using a stainless-steel pipe, a round shape is a natural choice.

It is very important that the heat riser is vertical (no tilting as this disrupts the flow of the flames) and that the surfaces are smooth and without irregularities. Use a leveler when building the riser.

The cross sectional area in relation to its height (E and e).

The dimensions shown in the graph are representing the largest relationship between the heat riser's cross sectional area (here 314cm^2) and its height (132cm).

Many rocket-builders claim that the acceptable height ($314cm^2$) is in the span of 88-132 cm, with higher heat and cleaner burn with greater height. 132/314=0.42
88/314=0.28
Ratio height to area ratio: 0.28-0.42
If the cross area instead is 196 cm2 (14x14cm), the height of the heat riser would vary between 55-82 cm.
Calculation area-to-height: 196x0.42=82cm 196x0.28=55cm

The top of the heat riser (F)

The top of the heat riser is where the temperature is supposed to be the highest and also where we want to use the heat or energy. It is very important that the cross sectional area of the opening (fig.4), also when we have placed a pot on top of it, never is smaller than the cross area of the burn chamber.

When we build a stove we are also trying to make a suitable solution for holding the pots or pans, preferably with an ability to adjust the heat. This is often done by increasing the distance between the exit of the rocket and the area on which the pan is resting and can be done with many creative solutions. We should here take into consideration the turbulence of air that will occur at the top and adapt the exit (A) so that it fits our pots or pans, as well as consider any protruding handle, f.ex from a frying pan.

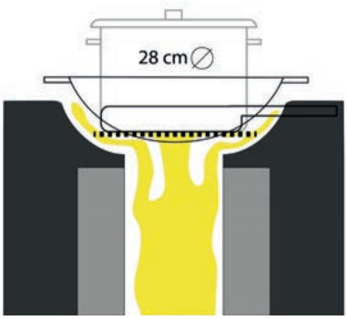


Fig. 4: Illustration of modification of the exhaust in order to reduce turbulence

Results, learnings and errors to avoid

If building the rockets according to these dimensions and proportions, there shouldn't be any real errors and the only thing that should be affected is the optimal functionality. There are many different modifications of the rocket, some creating more turbulens within the burn-chamber and heat-riser than others (resulting in increased friction), but it is up to you to find your own rocket and learn from others if you want to make modifications.

If the materials used for the heat riser or burn chamber can not handle the high temperatures, they will most likely crack You might have to then seal the rockets in order to reduce the risk of air being sucked in, or exhausts escaping. If the cracks are compromising the structural integrity, make sure that it doesn't result in any risks of collapsing and thus resulting in a safety risk.

Step by step guidelines for building the solution

Preparation

1. Determine the size of the rocket according to the needs. Make a schematic drawing of the design and measurements.

2. Determine what materials and methods to use for the build. If prefabricated elements, such as fire bricks or Leca blocks are chosen, do a calculation on the number of pieces needed for the build, with a few extra in case of small errors or adjustments. If a mold is used, make a sketch with the pieces for the mold and a schedule for the molding process.

3. Prepare the building site according to the dimensions of the stove. If the design requires the base of the stove to be under the ground level, start with preparing the ground so that there is proper drainage around the base. Make sure that the base of the rocket is built on a firm surface, either large stones or compressed soil/clay.

4. Make sure that you have a roof above the rocket and the building-site in order to protect it from rain, especially if using clay for the build as it will be sensitive to water.

Building the rocket:

These steps will differ depending on which materials or techniques you choose. The following steps are relevant if building the rocket with fire bricks and clay-straw insulation. Lay out the bricks first without mortar to find a good combination that makes up the right dimension for the feed tube, burn chamber and heat riser (you don't have to build up the entire heat riser at this point, just the first layers).

1. Start with making the flat base layer. Use a number of bricks and a suitable pattern according to the size of the bricks and your size of rocket. Mix a mortar with fine sand and clay (2 to 1) with water (the consistency should be like a loose pancake-batter) to attach the bricks together. Dip the sides of the bricks in the clay/sand slurry and use a brush to fill out any voids (you might have to wet the surfaces of the firebricks before dipping them in clay in order for them not to absorb the water too quickly). Have a more dry mixture of sand and clay ready as well for filling and sculpturing (the consistency should be that you can make a golf ball out of the mortar, throw it one meter up and catch it in your open palm with little deformation).

Scrap and clean of any extra mortar from the top of the surfaces. The goal is to make them flat and smooth, with the top of the bricks as a surface to the burn chamber.

2. Continue with the rest of the structure and make sure that the sides of the bricks that are attaching to each other are dipped in the mortar to create a good "glue". Make sure that the surfaces in the burn chamber and heat riser are straight and smooth, cleaned from any excess mortar. It is also important that there aren't any holes or gaps where air can get through.

3. When the structure is built and has had a chance to dry, check that it feels solid and doesn't have movements anywhere.

4. Mix a new, more dry mixture of sand/clay (3 to 1 in volume) with water, and mix this mortar with straw, equal amounts in volume (it can be good to use a tarp to mix the ingredients together).
Before the mix of sand, clay and straw is started to be applied around the bricks, starting from the bottom and going up, make sure that you water the bricks first, right before the mixture is put on them. This increases the bond between the bricks and mixture. Take your time to build up the layer, which should be about 10-15 cm thick. Don't make the outside surface too smooth, as the rough texture of this will be needed for the final, finishing layer.

5. When the first layer has dried a little, apply a finishing layer. Make sure that you water the surface of the first layer right before applying, as with the bricks. Mix sand and clay (3 to 1) with water. The consistency should be the same as the end of step #1. You may use broken

up horse manure to increase the strength of this layer (the small grassy fibers act as reinforcement, but not if the manure stays in their original shape as balls). Apply a 2-4 cm finishing layer to the rocket with this mixture. Make the surface smooth or make shapes/sculptures for beautification.

6. Make and fit the metal details of the solution, f.ex the fuel stop at the bottom of the feed tube or the holder (may be adjustable) for the pans at the top of the stove.

7. Protect the rocket from rain and let it dry out for a few days, depending on the climate (heat and wind) before using the rocket (if it gets heated up to full temperature too soon, the outside layers are in much greater risk of cracking). It is important that there's a roof over the rocket.

Starting the stove

8. When starting the fire, load up the fuels in the feed tube on top of a fire-starter material to get it started. Light a small piece of wood or ball of paper and put in the top of the rocket into the heat riser, or have a holder for a candle that is lowered down the top of the heat riser. This is called "priming", creating a draft in the rocket which lets the air and flames move in the wanted direction. Light the fuel at the bottom of the feed tube. The draft and flames should then directly go forward to the heatriser. It will take 5-10 minutes before the rocket is heated up and balanced, before the rocket effect really starts (it might take longer the first time if the structure still has moisture in it). Don't let it heat up too much during the first burn, so close the air-intake after 10 minutes and let it cool down.

Repeat the same procedure again but for 20 minutes, when cooled down (might take several hours). Experiment with the size of the air-intakes by reducing the size (e.g. with cut bricks, leca-blocks)

Observe if the rocket seems to function well and that the burn is clean. Observe the outside layer and examine it for cracks. Try to fill the cracks with mortar made of fine sand and clay (2 to 1). You can always fill any cracks that may appear at a later point with the same type of mixture.

9. If everything seems to work fine, start using the rocket. You can always make adjustments at a later point, f.ex improving the draft at the top of the stove, depending on your pots or pans, or make tools to change the distance from the outlet.

People, community, institution and/or organisation operating the prototype

Suderbyn Ecovillage, Sweden

Experts involved

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Author of the content

Martin Ahlström

CATEGORIES

WIND POWER
EDUCATIONAL

Wind turbine model

Educational, energy source for very small needs

Short intro

Wind turbine model is a working device demonstrating the principles of wind turbine operation. It is a simple easy-to-build turbine with an optimally designed, efficient blade set that can light an LED bulb using a small house fan. It consists of several basic wind turbine components (foundation, tower, generator, nacelle, hub and blades) and is capable of generating a certain amount of energy. Wind turbine model rotates under the impact of air stream coming from a fan and the integrated generator produces electricity.
Max generating voltage - 2,4 V, current - up to 20 mA, power capacity - up to 48 mW.

Complexity of building, operating and cost of the solution

Low

Model can be assembled from prefabricated parts in several minutes. Blades take more time to make, because they hand made by the user from cardboard, balsa wood or plastic materials.

Cost of the materials for this model can reach up to 50 EUR.

Description of the solution

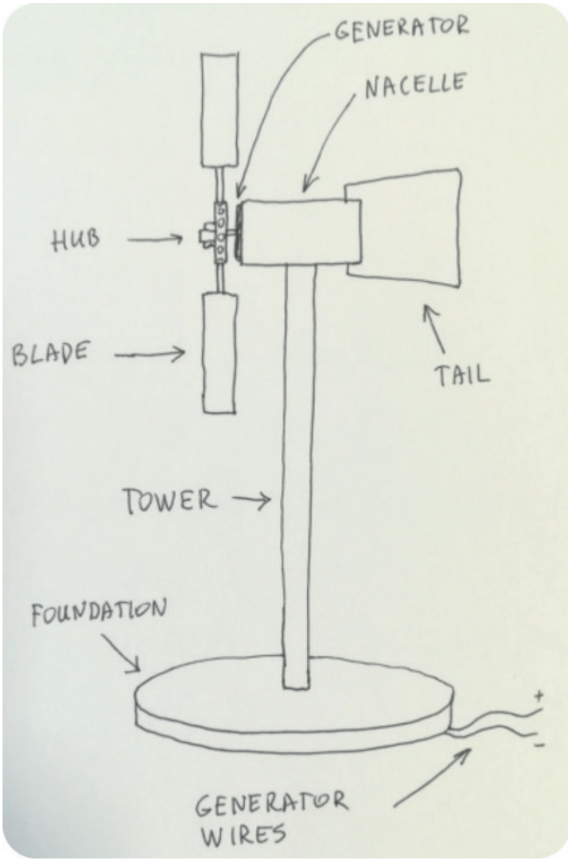
Wind turbine model in its shape reminds of real wind turbines, but it is not a desktop replica of a certain turbine. It serves as an educational device and provides possibilites for wind energy research activities at school or college level.
The model allows students to explore basic wind energy production and blade design concepts such as pitch, area, mass, quantity, and material on a desk using a small house fan.

All parts are available to purchase as ready-to-use, but it is also possible to produce parts at home from materials available at technical stores.

Foundation can be made of a round timber or plywood plate (diameter 150 mm), you will need to drill a hole at the center for the tower. Tower is a small aluminium pipe.

The nacelle given in the picture is prefabricated, but that fancy form can be replaced by a piece of plastic tube with diameter suitable to accommodate a small DC generator tightly.

Wind turbine tail (small plastic plate) can be attached to the nacelle. Hub is the most difficult to fabricate and should be purchased separately. The blades are made of 7 mm diameter wooden stick and a rectangular piece of cardboard or thin plastic.



Materials, skills and tools required

To make this wind turbine model at home one will need some simple materials and instruments (apart from the parts which need to be purchased):

- round wooden plate
(10-20 mm thick, 150-200 mm diameter);
- aluminium pipe
(length up to 350 mm, outer diameter 15-20 mm);
- plastic tube
(length 50-70 mm, inner diameter 32 mm);
- plastic plate
(30x80 mm, 2 mm thick);
- generator
(voltage output: 0-10 V, current output: 0-0,3 A, diameter: 31,75 mm, shaft diameter: 2 mm);
- hub
(available at https://www.vernier.com/product/kidwind-wind-turbine-hub-3-pack/);
- wooden sticks
(diameter 7 mm, length 120 mm)
- cardboard or plastic plate
(80x200 mm, up to 3 mm thick)

Results, learnings and errors to avoid

The blades are the main part of the model and have a huge impact on how well the turbine works. Some experiments should be performed to see which blades work best. Blade-variables to test include: length, shape, number, materials, pitch, and weight. Here are some quick tips on improving blades:

• Shorten Blades. Althoug in real life turbines with longer blades have better energy yield, in this case long blades add more drag. Shortening them a few centimeters might have substantial influence on rotation speed.

• Change the pitch. Pitch dramatically affects power output. Often, students set the angle of their blades to around 45° the first time they use the turbine. Several experiments with a different pitch angle will show the trend. If the blades are attached and they are not spinning, you should check the pitch.

• Use fewer blades. To reduce drag, you should try using fewer blades.

• Use lighter material. To reduce the weight of the blades, it is advantageous to use less material or lighter material.

• Use stiffer material. If the blades are bending in the wind or deflecting when the wind hits, you should find a stiffer material.

• Smooth surfaces. Smoother blade surfaces experience less drag. A blade with lots of tape and rough edges will have more drag.

• Get more wind. Wind turbine model is driven by an air flow created by a room fan. Make sure you are using a sufficiently powerful fan to rotate your model.

• Blades versus fan. Blades may not turn fast because they may be bigger than the fan. This could be a problem, as the tips of the blades are not catching any wind and are just adding drag.

• Blade shape. Blade tips travel much faster than the roots. This fact may help solving rotation problems as wide tips add drag.

Activity ideas

This model can be used to carry out fun experiments, explore various parameters and further improve its design. Parameters of generated electricity can be measured with a multimeter (in case of power – a couple of them) or any more sophisticated device. Power is calculated by multiplying voltage (measured in volts) and current (measured in amps).

By changing the number of blades, their pitch and shape one can determine which rotor design is most efficient as all these parameters influence the rotation speed and energy generation. Also energy output can be recorded under different air flows – various distances from the fan or different fans may be used for this test.

Last but not least – different generators can be tested on the same model. Make sure to use a nacelle with right diameter to fit the generator tightly.

Step by step guidelines for building the solution (see images after the list)

1. Prepare the foundation

Find or cut a round wooden plate and drill a hole in the center. The diameter of the hole should match or be slightly wider than the outer diameter of the tower. It can be useful to attach few small pieces of rubber or few drops of hot glue at the bottom of the plate to prevent slide on smooth surfaces.

2. Insert the tower

Tower should fit tightly into the hole otherwise the turbine may vibrate or bend during operation. In case the tower is too loose, add some plastic tape on the lower end. Tower should be hollow as the generator wires will be put through it.

3. Make the nacelle

Construction of the nacelle requires some skills. First of all a generator (small DC motor) must be purchased, many of them are available on eBay or Amazon. Motors with lower rotational speed are recommended.

(e.g. https://www.amazon.com/Topoox-1730RPM-Electric-Turbine-Generator/dp/B07Q44YYKG/ref=sr_1_7?keywords=mini+dc+motor&qid=1579767658&sr=8-7).

Once you have a generator the next task is to find a plastic tube with the inner diameter matching the dimensions of the generator. If tube is slightly wider, you may want to put some plastic tape around the generator. Hot glue may also work, just make sure that generator shaft position is horizontal.

Tail is optional: if the nacelle is attached firmly and cannot whirl, tail won't have influence on the yaw position. If the nacelle can easily turn horizontally then tail may add stability to the rotation of the rotor and consequently energy generation. Finally, a hole should be made in the bottom of the nacelle to draw the generator wires down.

4. Attach the nacelle to the tower

If the nacelle is made of a straight tube, it can be attached to the tower with hot glue, right under the hole with generator wires. If a bent tube is used for the nacelle, then it can be just fixed tightly on to the tower. Make sure the nacelle is not too loose, otherwise you may have an unstable turbine operation.

5. Design the blades

Blades typically consist of a wooden stick and a piece of cardboard. It would best to glue the stick to the cardboard, but it can also be attached with an insulation tape. It's most important to attach it strongly so that the blade doesn't break apart when rotating at high speed.

Next task is to shape the blade: you can use your imagination here, because you never know which design works best. There are some basic principles described in Chapter 6.5.

6. Assemble the rotor

Rotor is assembled by putting the blades in the right holes of a hub. Design of a rotor depends on the number of blades used. There are 12 holes in the hub, so you can use 2, 3, 4, 6 or 12 blades to construct a symmetric and balanced rotor. Make sure you use the right pitch angle.

The assembled rotor is simply placed on the generator shaft.

7. Prepare test equipment and have fun!

Wind turbine model test equipment consist of a fan and a multimeter. Also you can use portable anemometer to assess wind turbine output under different wind speeds.

If any kind of load is used (LED, buzzer, etc.), generated power can be estimated by using two multimeters: one connected in series, showing amperage, and the other connected to the load in parallel, showing voltage. Power is calculated by multiplying voltage and amperage.

Fig. 1: The base

Fig. 2: Insert the tower

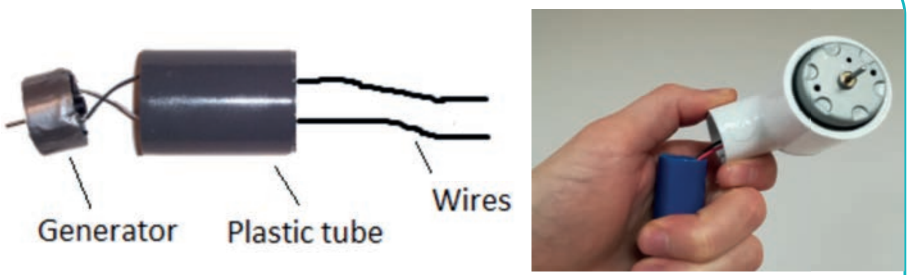


Fig. 3: Make the nacelle

Fig. 4: Design the blades

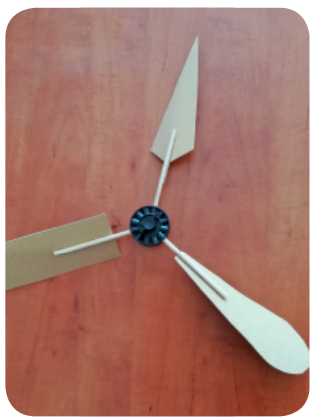


Fig. 5: Make the rotor

Fig. 6: Assemble the parts

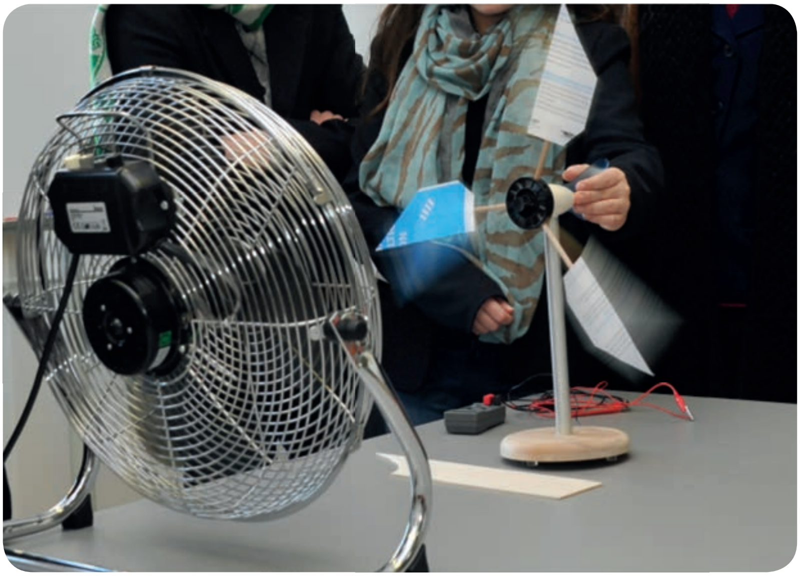


Fig. 7: Prepare the test-equipment and
have fun!

8.Video of the solution building workshop or process

-Video from Kaišiadorys LAG workshop - https://www.youtube.com/watch?v=CtKmxtCMJgA

9.Relevant links and articles

Wind turbine model parts are available here: https://www.vernier.com/product-category/?category=kidwind At vernier.com and kidwind.com you can also find a large amount of educational information, advise, curricula and ideas for both students and teachers.

Geographical territory

In schools of Kaišiadorys district

Context of the prototype

students retained prototypes after the workshop.

Who are the people, communities, institutions and organisations operating the prototype?

Schools.

Experts involved:

Dr. Mantas Marciukaitis, Head of the Laboratory for Renewable Energy and Energy Efficiency at Lithuanian Energy Institute (www.lei.lt)

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5. Introduction to more solutions

You just got to see four of the solutions with a more or less full description, even though there is more material online, for example videos, comments and different versions or modifications.

In this last part of the book you will find a few short introductions of some of the other solutions that you will find on the platform.

CATEGORIES

SOLAR
ENERGY STORAGE
RENEWABLE ENERGY

Solar triangular house Trian-S

TRIAN-S is a prototype of a wide purpose offgrid solar electricity production unit with usable room under the solar panels.The general idea is to use the space under the ground mounted solar panels, so we can economize resources of land.

The frame (stand) for the solar panels makes the room we can use for multiple purposes: from storage to accommodation. The roof is made of solar panels, which are producing electricity with a capacity depending on the type and number of panels, normally with 2,5-5 kW peak effect and a yearly production of 2500-5000 kWh.

It is also possible to combine building units in different ways, resulting in a larger building and more options for use.

The use of the building reduces the ecological footprint due to environmentally friendly electricity generation and the integration of the materials used.

Experts involved:

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CATEGORIES

HYBRID SYSTEM
HEATING

Combined heat and power emergency system

The Combined Heat and Power Emergency System (noted as System further on) is a junkyard derived solution to provide emergency power & heating from local wood resources during times when sunshine, wind or hydro are unavailable, like in winter months for emergency situation.

The solution given here describes the base unit with no automation, utilizing commonly available junkyard parts and some hardware store parts. The system can operate either on wood gas, which can be replaced for warmer months with biogas, or enhanced further with the ability to utilize solar, wind and hydro power instead.

A wood gasifier, the modified U.S. Federal Emergency Management Agency (FEMA) design, is used. Wood gasifier provides heat for water and space heating and provides the wood gas required to fuel a modified lawn mower engine, which runs the electric power generation through a modified car alternator. This engine is started manually either by pull cord, electric starter or electric drill. Once the engine starts, the operator switches the alternator on to charge a 24 V DC battery bank. The battery bank can utilize scavenged car/truck batteries that may no longer be adequate for vehicle starting, but are still quite capable for home power storage.

The system provides around 6 kWh of battery storable power from 3 hours burn time, which is a typical burn time for home furnaces in winter. An inverter can be attached to the batteries to convert 24V DC to 230V AC suitable to power home appliances/tools. A 5kW inverter would be adequate for most homes, however lower capacity power inverters will work too, so long as care is taken to appliances power ratings and simultaneous appliance usage.

The battery storage amount will provide for basic living needs if used with care. Expansion for more stored power is as simple as adding duplicate generator units or higher rated engine and multiple alternators and additional batteries.

Experts involved

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CATEGORIES

CLOSED LOOP, FERTILIZER & HEAT

Biogas - fertilizer & heat

In small scale biogas-production, organic waste from households and gardens are being used to make fertilizer for plants and raw biogas for heating. By letting microbes break down the biomass in an anaerobic (oxygen low) environment, methane (about 60% in raw biogas) is produced as well as a fermented nutrient substrate, suitable as fertilizer.

The process is taking place in an enclosed digester and at 38-40°C as optimal temperatures, even though the microbes can be active down to 15-20°C, then with lower efficiency. This means that the system needs an external heat-source to function well which results in a less than optimal energy-efficiency for the entire system and the size and design of the solution has a great impact on its energy performance.

For this reason it is the locally produced, fossil-free fertilizer that is often considered to be the main product in small scale biogas and the raw biogas can be used for heating or cooking.

Experts involved:

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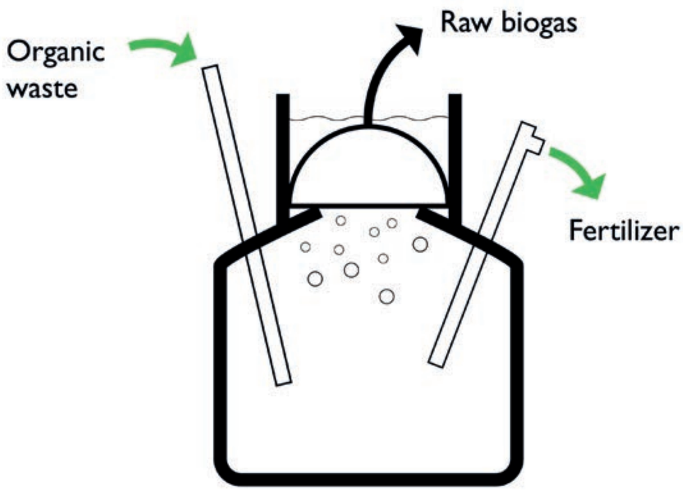


Example of a Puxin-model digester with no moving parts


Example of a digester made from an IBC tank


Example of a filters and scrubbers for the raw biogas

CATEGORIES

KINETIC/MECHANICAL

Velo Washing-machine

Velo or pedal-power solutions are one way for us to utilize our own bodies to perform work. This means less dependence on electricity and electrical systems and a more active lifestyle. Pedal-power can be applied for multiple solutions where kinetic energy is the main output.

One way of using pedal-power in our everyday life is to power a washing machine, a solution that allows for the use of widely available waste-materials. An electrical washing-machine with damaged motor or other electrical components can function well with pedal-power as its structure and drum can be directly connected to an old or damaged bicycle.

By pedaling back and forth, alternating the directions of the drum, the movement is mimicking that of an ordinary machine. The pedaling does not have to be constant during the time of the wash, but can be done in short bursts as the textiles need to soak between rotations.

Experts involved:

Elgars Felcis - elgars.felcis@gmail.com

Gatis Kreicbergs - gatis8@inbox.lv

Examples of contruction and usage of parts
from old washing machine and bicycle

CATEGORIES

ELECTRICAL PRODUCTION

Hugh Piggott Wind-power

A Piggott small scale wind turbine is a solution that can have great value in windy locations and complement solar for electrical production. The maximum output from a Piggott model is often 800-1000 W as larger installations become difficult to handle without specialized equipment due to their size and weight. The wind turbine's generator is most commonly connected to a battery bank for so called trickle charge through the use of inverters and regulators. Versions of the turbine can also be connected to a grid if wanted.

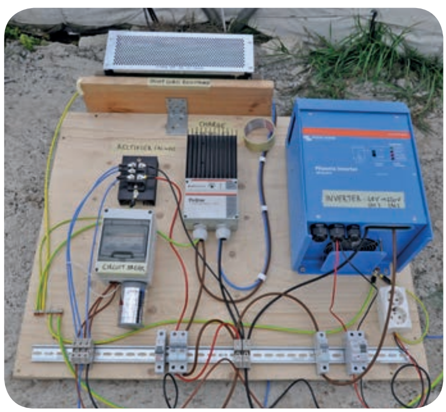
The entire system is DIY (apart from some electrical connections when under regulation) and detailed instructions are available for a small donation.

Experts involved:

Simon Goess - simon.goess@gmail.com

Example of Hugh Piggott wind-turbine

The DIY stator and axel for the tail



Electrical components for charging batteries

CATEGORIES

SPACE-HEATING

Rocket Mass Heater

There is a detailed description of the rocket-stove earlier in the book and here is a short introduction of what might be the most efficient usage of a rocket, the rocket-mass-heater.

By letting the heat and exhaust from the rocket travel through a system that is surrounded by thermal-mass, a maximum amount of the energy is being used to heat the building before exiting the chimney. For a large rocket (cross-section-area of about 315 cm2) the length of the exhaust can be up to 9 meters and be surrounded by a mass of total 5-6 tons. If the temperature in the rocket reaches 1000°C, and the exhaust temperatures when leaving the building is 100°C, 900°C is being used for heating.

The rocket-mass-heater provides a comfortable heat that is starting to radiate about 10 minutes after the start of the burn and will be stored in the mass for up to 10 hours. Many creative solutions can be made for the distribution of the heat and the mass can for example be made into a bench/sofa, a bed or a wall, all acting as a radiator when the energy has been stored in the mass.

Experts involved:

Martin Ahlström - martin.ahlstrom@gmail.com

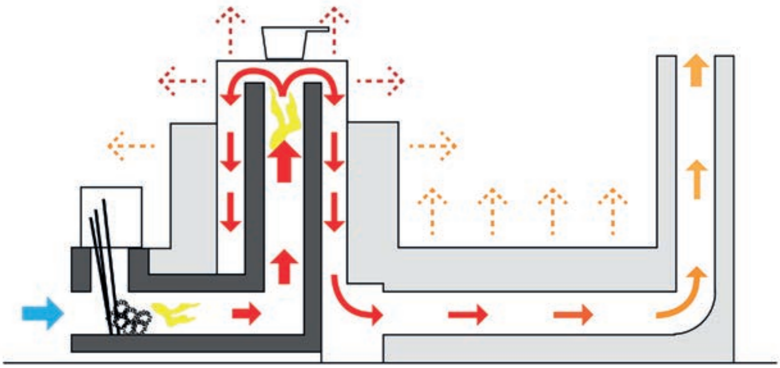


Illustration of the heat-transfer and radiation
in a rocket-mass-heater

Example of an installation in an outdoor kitchen under construction.
The mass for the exhaust will still be added, here
consisting of rocks and clay

CATEGORIES

SOLAR-POWER
EDUCATIONAL

Solar racer model

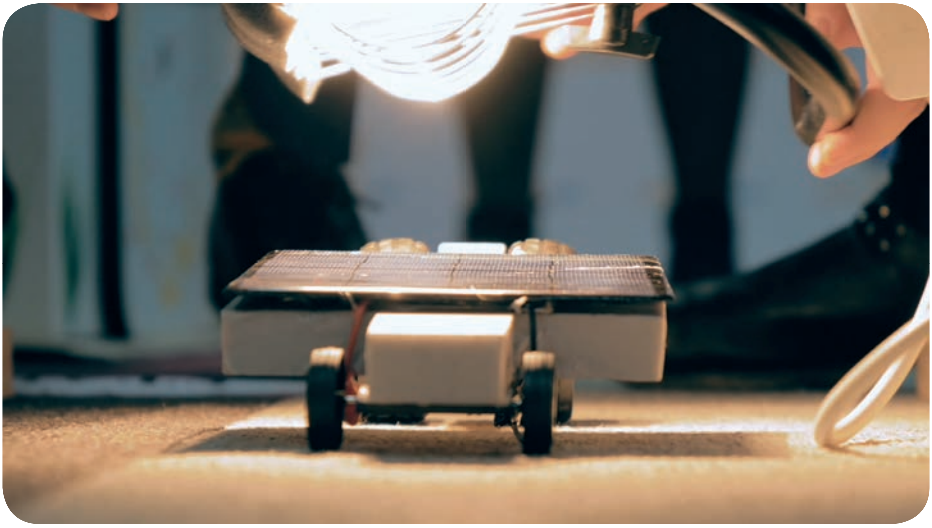
The Solar Racer Model is a simple device which can be used in school science projects and as an educational tool. The model demonstrates alternative energy concepts while incorporating problem solving, design and modeling and can provide useful practical and theoretical insights connected to solar-power and its potential usages.

Construction of the Solar Racer model also gives students the experience of using hand tools as they have to make everything by themselves. The PV cell of the Solar Racer Model generates voltage of 6 V, current - up to 50 mA, power capacity - up to 300 mW.

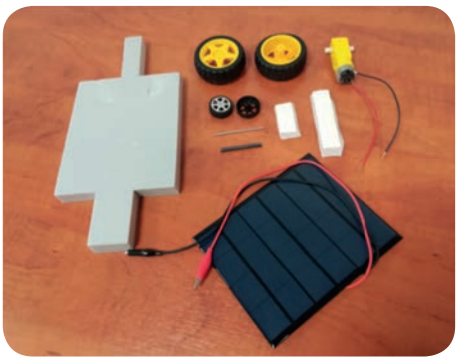
The system does not include any batteries for storage but artificial light can be used to control or experiment with the power-source and the effect it has on the performance of the model.

Experts involved:

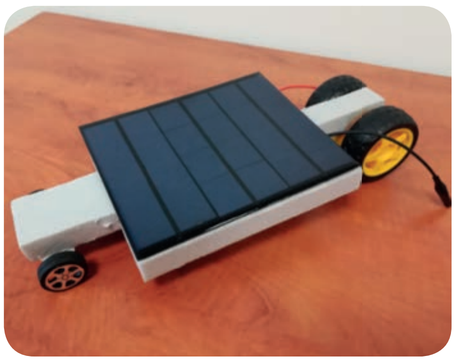
Dr. Mantas Marciukaitis



Using artificial light as a power-source for the small PV-panel



Parts for assembling



Final model, ready for racing

Thank you!

All of us that have been working on the Off-Grid DIY project hope that some of the content in this book will inspire you to take new steps on the journey towards your fossil-free future, and that you see that you're not traveling there alone.

The choices that we must make, both as individuals and as a society, will not always be easy but by sharing our experiences from attempts of living with more sustainable solutions and behaviors, maybe we can both help ourselves and each other.

www.off-grid.rocks

Off-Grid DIY Renewable Energy
for Rural Development

Off-Grid DIY Renewable Energy for Rural Development

This handbook is one of the results from the LEADER-funded project "Off-Grid Do It Yourself Renewable Energy for Rural Development" (2019-2020). It is meant to inspire you do make smart and concious decisions, with a few of the technical solutions explained step-by-step. You will for example learn how to produce warm water for heating while making soil from compost, or how to make and optimise your own PV installation (solar-electricity).

Another result from the official project is an online platform, **www.off-grid.rocks**. Here you will find more information connected to the topic and solutions that you find in this book, and many more.

We hope that you will be inspired to engage with the community and become a part of it. Maybe you want to contribute with your own experiences, success and failures? In this way we can all learn how to shape and live in a future with less fossil-fuel dependence, stronger local engagement and increase resilience as the world and climate continue to change.

LEADER

The European Agricultural Fund for Rural Development: Europe investing in rural areas