# Principles for ecological planning in rural context

## Case New Dalby Village on Orust

**Tuomas Ranta-aho**

# Recital

Global warming is a scientific fact. We are using more resources than the Earth can provide and at the same time we are emitting huge amounts of greenhouse gasses that already impact the natural state of ecosystems. Built environment is the largest single resource user in the world and one of the largest energy users. To keep the Earth livable in the future we have to radically rethink how we live, eat and use our dwindling resources.

This paper is a tool to reflect different aspects of sustainable development of built environment in local context. The paper states that all thinking must change and we have to include environmental goals to every level of our decision making. To meet the emission targets of the international agreements we have to cut down our current greenhouse gas emissions by 80-90 %. At the same time we need to cut down our increasing use of resources, especially our use of non-renewable resources.

In the context of the built environment these ambitious goals can be achieved by applying many different methods depending on the scale and site of the project. This paper seeks both theoretical and comprehensive solutions and studies their implementation in an example area – in this case the new village of Dalby on the island of Orust in Western Sweden.

The first part of the paper collects different theories, methods and examples for effective and sustainable resource use and lower carbon footprint. The most effective methods and theories are collected into a checklist in easily reachable format for municipal planners. In the second part some of these theoretical methods are used to make overall plan for a new ecologically sustainable neighbourhood in Dalby.

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**Author:** Tuomas Ranta-aho

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# Part 1:
# **Theory**

# Planning a rural ecological village or neighbourhood

It is challenging to determine what is ecological or sustainable, the concepts are complicated and ambiguous. Do we state that in order to define something as ecological, we need to minimize damage to ecosystems or do we actually try to recover already destroyed natural systems with our planning? What do we consider an acceptable level of damage or emissions?

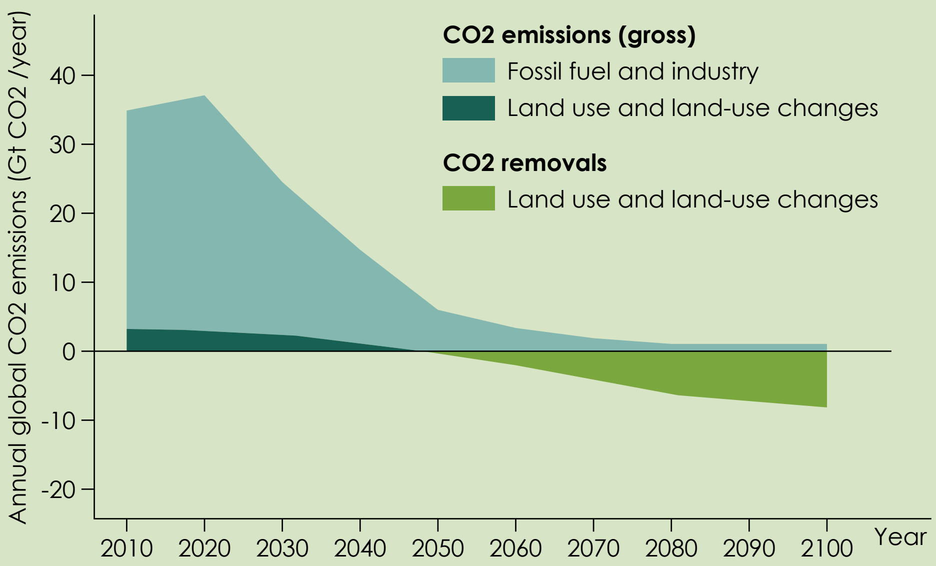
The European Union, the United Nations, Sweden and Orust all have their own goals and interpretations of what they consider to be ecological. As Orust has ambitiously set their goals to reach "climate and energy neutrality", the goals and viewpoints of this paper are set in an equally ambitious way.

## Environmental goals and targets

In this paper, environmental aspects and sustainability are analysed from **three** different points of view. All solutions and theories introduced in this paper significantly improve current practises in at least one of these three areas, preferably in several. The first viewpoint is the evaluation of the greenhouse gas emissions that different building solutions and our current lifestyle are causing. The second is the analysis of the ecological footprint, and the third is the use of harmful and non-renewable materials.

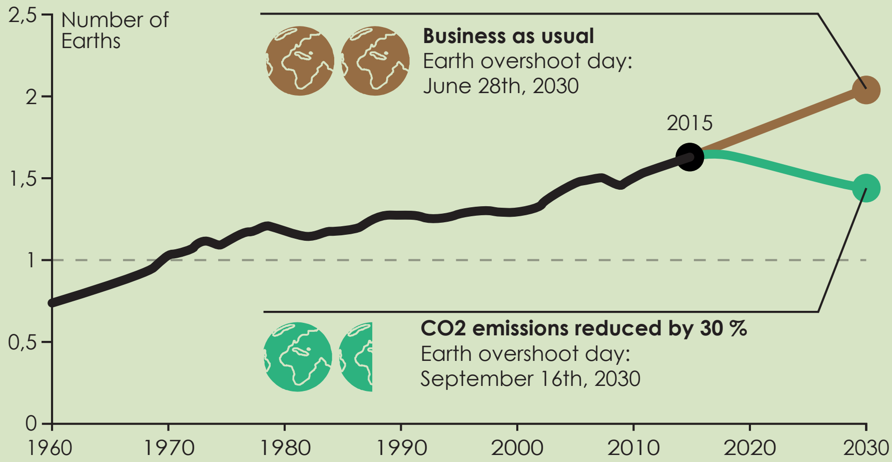
To reach a sustainable level of **greenhouse gas emissions** in the long run we need to cut the emissions dramatically. Johan Rockström (2017) states that we need to cut down emissions by 50 % every decade from now on and be totally carbon free in 2050. According to the European Commission (2011) we need to cut down our emissions before 2050 by 80 % compared with the emissions of the year 1990.

**Required emission cuts to limit global warming under 2°C**




*To reach Paris agreement's goal to limit global warming under 2°C we need to cut CO2 emissions by 50 % every decade. Source: Rockström, 2017*

## Ecological footprint of the world and possible futures




*The World's overshoot day represents the date when our use of resources exceeds the world's capability to regenerate those resources that year. Source: Global Footprint Network, 2017*

**Ecological footprint**, the land that is needed to support our current lifestyle, is currently 1.6 times the area of the Earth. It means that it takes over 18 months for Earth to produce our resource usage and to absorb our waste. The current ecological footprint for a Swedish person is 7.25 global hectares (gha). A global hectare is a unit that represents the biological productivity of an area per year. The average global biocapacity (nature's capability to produce) is 1.73 gha. It means that if the world's population lived like the Swedes, we would need 4.2 Earths. (Global Footprint Network 2017)

The third factor we are analyzing is the use of **harmful- and non-renewable materials**. Like the name of these resources implies they are limited and using them is only pushing the problem further. In his master's thesis Lars-Erik Mattila (2014, p. 21) divides materials in three categories. The first category includes renewable materials like wood and natural fibers, which are natural and safe if they end up in nature. The second category contains harmless non-renewable materials like stone and clay. The third category encompasses non-renewables like plastics that are toxic or harmful if they end up in nature.

In his four laws of ecology, Barry Commoner (1971), states that everything is connected and our human civilization is not a separated system from nature. Therefore in this paper the natural flows and circulation of materials are emphasised.

### The four laws of ecology

1. Everything is connected to everything else. There is one ecosphere for all living organisms and what affects one affects all.
2. Everything must go somewhere. There is no "waste" in nature and there is no "away" to which it can be thrown.
3. Nature knows best. The absence of a particular substance from nature is often a sign that it is incompatible with the chemistry of life.
4. Nothing comes from nothing. Exploitation of nature always carries ecological costs and these costs are significant.

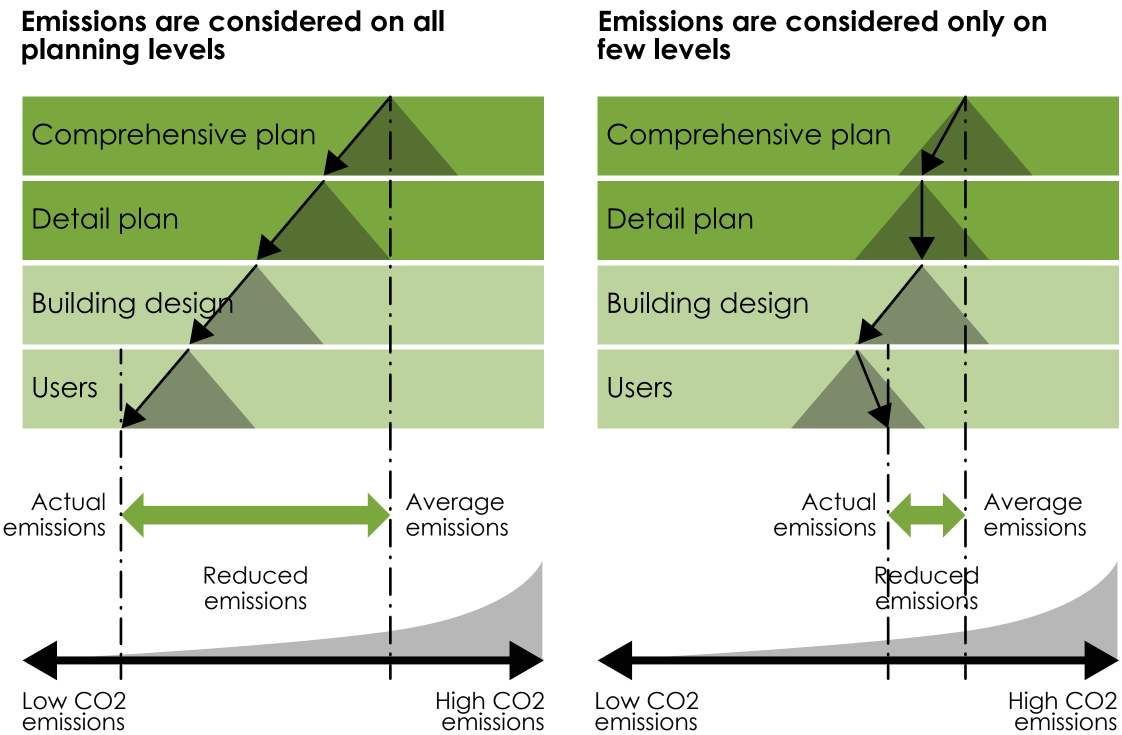
*Barry Commoner, The Closing Circle, 1971*

## Different planning scales

Areal planning of urban and rural areas differ a lot, which is why different planning methods and emphases are needed. To achieve a sustainable end result the different levels have to function together. That is why it is very important to define goals carefully and throughout the entire process check if the chosen methods work with the goals.

No single planning level alone can make a difference. The purpose of implementing comprehensive planning levels is to enable sustainable solutions with suitable land use and transportation network. These along with the supported energy solutions are the most effective ways to cut down emissions in general planning level. (Nysted, Sepponen, Virtanen 2012, p. 3)

According to a publication by Aalto University about environmental detail planning (Lylykangas, Lahti, Vainio 2013, p. 17), the detail serves the purpose of making a sustainable lifestyle possible. Large scale planning should not be an extension of building regulations but a document to support the existing characteristics of an area and to combine them with future needs. The best end result is achieved when all different planning levels from comprehensive planning to building phase and end use consistently execute mutual environmental goals.




*The best effectiveness is achieved when the environmental decisions are taken on all levels of planning and executing. The common goal is mandatory to pass on from planning level to another to gain maximum benefits. Source: Lylykangas, Lahti, Vainio, 2013*

## Elements of eco village

There are many different ways of achieving a more ecological end result. In his master's thesis *House 540*, architect Pekka Hänninen (2016) studies different ways of limiting the greenhouse gas emissions of a one family house to under 540 kg CO2e / year per person. In the thesis he compares different methods and states that the site and materials available for each project are very essential factors when planning eco-friendly buildings.

In larger scale like in towns or villages, there are even more methods to ecological planning. The key factor is to identify natural characteristics of an area and find the most effective solutions to that specific area.

According to a study by VTT Technical Research Centre of Finland called Design principles for rural eco districts (Nysted, Sepponen, Virtanen 2012, p. 13), the basic elements of an ecological rural area are a dense town structure, sustainable energy production, consumption and transportation methods and ecological water and waste treatment. The study states that each of these aspects have to be carefully planned with consideration of all other aspects at the same time. This paper uses elements that are based on the ideas of the aforementioned study but adopted on Orust. The VTT study concentrates especially on energy efficiency and since this paper defines ecological planning more broadly, the focus is on the use of materials and local agriculture.

Next, the different elements that need to be considered when planning an ecological village, are discussed. In the next part there are comparisons, theories and various examples that cover different aspects of ecological rural planning.

**Different element in this paper are:**

**Typology and building patterns**
Land use changes
Building patterns and placement
Building orientation
Volume and size

**Materials, technology and building techniques**
Ground conditions and foundation techniques
Material emissions & stored carbon
Use of renewable and non-renewable materials
Lifespan and technology dependency

**Energy**
Energy efficiency
Energy production

**Food production and local agriculture**
Carbon smart agriculture
Permaculture

# Typology and building patterns

Effective land use is always a landowner's priority. Both in urban and rural areas the current detail plan is a powerful tool to guide building patterns and typology towards more sustainable solutions. Nevertheless, it is often in the power of the builder and the end user to make sustainable decisions. That is why it is important to carefully separate building regulations from planning ordinance (Rodriguez-Gabriel 2016).

According to Rodriguez-Gabriel (2016) the detail plan is more of an enabling than directive tool what comes to sustainable solutions. A plan can either enable better and more sustainable solutions or make them impossible to implement on site. To reach ambitious goals effective building regulations and legislations, not to mention careful and responsible execution, are needed to support good detail plan.

## Land use changes

One of the large causes for increases in greenhouse gas emissions are the changes in land use. Nature can function as either a carbon sink or a carbon dioxide emitter depending on the vegetation. For example, growing forests function as carbon sinks. Thus, every time the forest is cut down, it has an effect on Earth's capability to handle carbon dioxide.

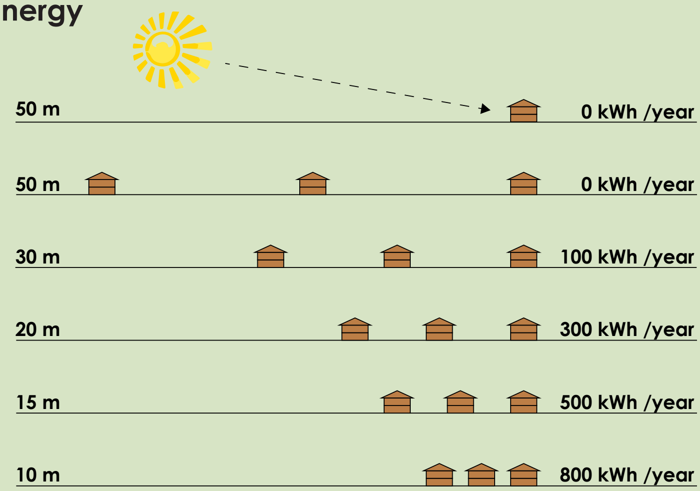
Globally most of the land use changes are caused by cutting down forests and turning the land into fields. The emissions caused by arable land can be reduced with the right kind of farming techniques. These measures are further discussed in chapter "Carbon smart agriculture" (Mattila, 2017). Land use changes need to be included in total emission calculations when building new areas (Lylykangas, Lahti, Vainio 2013, 29).

*In Finland the new fields are usually created by cutting down forests and burning the remainings. This technique grants lots of nutrients to plants but it causes lots of emissions as well. Picture: Finnish forest association.*

**Reduction of insolation energy**

*Even in Sweden's latitude the right kind of spacing can reduce the need of warming energy.*

*This graph shows the impact of different building placements on insolated energy caught by the house.*




*Source: Hans Eek, Passivhus Centrum*

## Building patterns and placement

Microclimate, or local climate conditions on the building site, have significant effect to a building's sustainability through the energy use, need of maintenance, lifespan and impact on surrounding nature. With careful building placement the microclimate can be used as a resource. Building placement can also be an effective way of protecting the building from extreme weather and make it more durable.

When lowering energy consumption the maximization of sunlight is one of the key factors. Nysted, Sepponen and Virtanen (2012, 18) mention the passive sunlight use as a principle for energy efficient construction. To take full advantage of the sun the houses need to be placed far enough from each other so that sun beams can touch them for as many hours per day as possible. This is especially important during winter months when the sun shines from lower angles and the heating requirements are higher. From the effective land use perspective especially southern slopes are good for this because they enable denser building patterns than flat surfaces, while maximizing the amount of sunlight. Straight sun beams and sufficient space between buildings also increase the effectiveness of solar energy production. More about passive and active solar energy use can be found in chapters on *Building orientation (p. 14)* and *Energy* (p. 23).

Constructing loose patterns can also work against the sustainability goals. Depending on the selected heating method the more dispersed structure can increase the distance that hot water needs to be moved from the heating plant to the houses. In larger scale, more dispersed building patterns cause increases in emissions by transportation. The transportation in rural areas can cause nearly half of the greenhouse gas emissions. The fact is, that the dependency on cars is higher in rural areas. The need for transportation can be reduced with zoning services closer to residential areas. (Nysted, Sepponen, Virtanen 2012, 13.)

## Building orientation

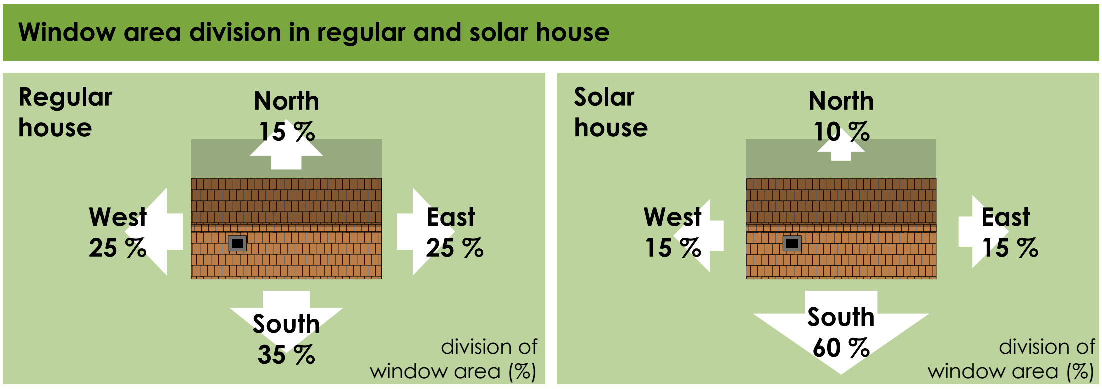
Orientation of buildings makes a significant difference in the energy usage of the buildings. According to Lylykangas (2014) a building that is designed to use passive solar energy could reduce the need for heating energy up to 31 % even at Luleå's latitude. This requires careful planning throughout the whole project. One effective way to include passive solar energy use is to control building orientation and placement through municipal planning, for example with detail plan.

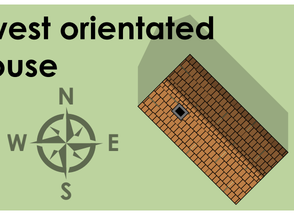
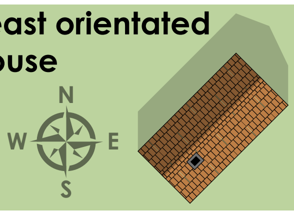
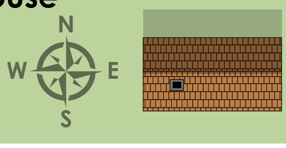
Finnish architect Bruno Erat built his own house, Villa Solbrante, in 1970s in Espoo, southern Finland. Erat was ahead of his time with his solutions like thicker insulation and use of passive and active solar energy. The house is orientated so that the longer edge is towards the sun and most of the windows are on the southern side of the house. Active and passive solar energy is stored in the 10 cubic meters of warm water in the bearing wall of the house. Living spaces are on the southern side of the bearing wall and other spaces function as buffer zones that can be heated if necessary. Villa Solbrante needs to buy only one fifth of the energy bought by an average house of the same era. (Erat 2016.)

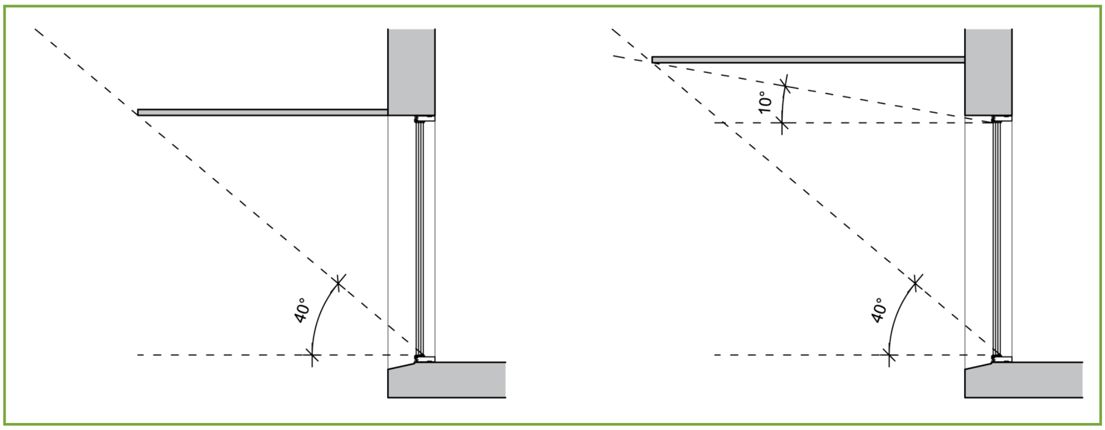
Passive solar energy can also be a problem if overheating is not taken into account in planning. Overheating during summer time can be avoided with proper eaves that shade southern windows from high angle sun beams (Lylykangas 2016). Another effective way that could also support the idea of local farming is to use broadleaf trees in front of the southern facade. Trees drop their leaves before winter when passive solar energy is needed and shade during summer when overheating is a problem. (Hänninen 2016, 43.)

*Villa Solbrante's windows face mainly south and the house uses passive and active solar energy for general heating and heating the service water. Picture: Bruno Erat.*

*Lylykangas (2014) has calculated heating energy in different orientation cases for solar houses compared to regular house (lower picture). Difference between solar house and regular house is only the window orientation (upper picture).*




| Orientation | Regular house | Passive house |
|---|---|---|
| **South-west orientated solar house**   | Reduced energy consumption: **4-15 %** **(max. 20 %)** depending on total window area | Reduced energy consumption: **5-20 %** **(max. 26 %)** depending on total window area |
| **South-east orientated solar house**   | Reduced energy consumption: **4-14 %** **(max. 19 %)** depending on total window area | Reduced energy consumption: **5-19 %** **(max. 25 %)** depending on total window area |
| **South orientated solar house**   | Reduced energy consumption: **5-17 %** **(max. 22 %)** depending on total window area | Reduced energy consumption: **7-24 %** **(max. 31 %)** depending on total window area |




*Proper eaves reduce the need for cooling during summer time. In this example sun rays of angles larger than 40° are blocked. The example on the right lets in even more low angle insolation. Picture: Lylykangas, 2016*

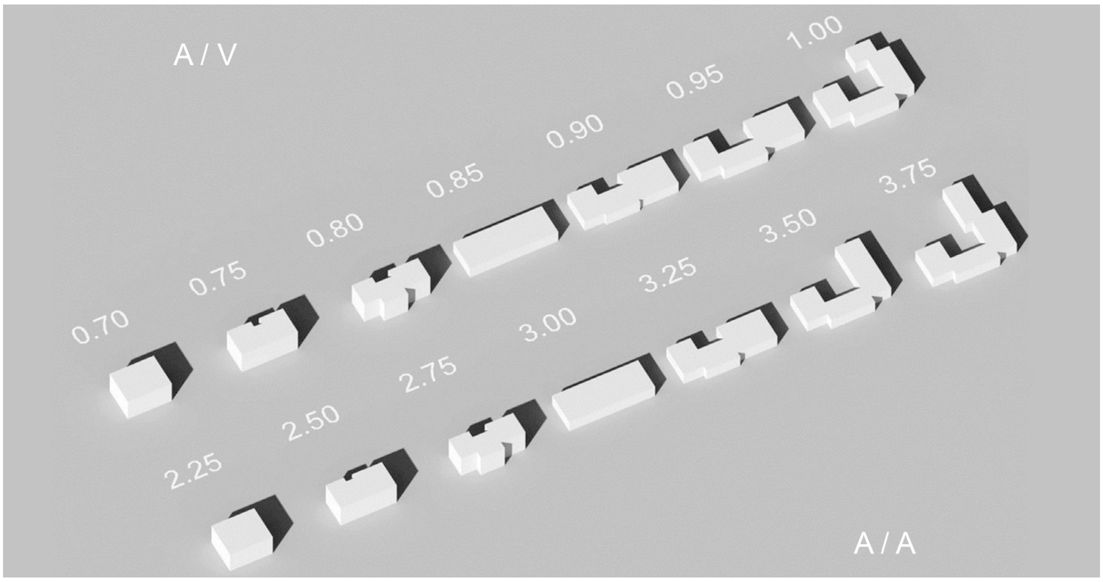
## Volume and size

Construction always starts, or it should, from the demand. To make housing sustainable it needs to be something that the people feel connection to and are ready to commit to. That is why it is hard to say if certain house types are better than others. Planning should be started by discovering the local needs and characteristics and after that keeping the sustainable goals through the entire process.

Architect Hänninen (2016) states in his master's thesis that sustainable low carbon housing can be achieved with single family housing even though it is often considered less sustainable than large and dense housing units. However, Hänninen mentions that regardless of housing type, considering the size of the apartment or house is crucial. Less heating energy and building materials are needed if we live in smaller homes and share more spaces with other inhabitants.

To a certain limit larger buildings are more energy efficient than smaller ones. One way to compare energy efficiency of same sized buildings is the **form factor**. Form factor can be calculated by dividing the building envelope by usable area or building volume: the smaller the number, the more effective form. Even more accurate comparison is achieved by weighted form factor, in which the area of the building's envelope is multiplied with the U-values of different structure types (walls, roofs, windows etc.).

In the Nordic countries, where energy efficiency is a carefully monitored factor in the building process, the efficiency rate is measured by dividing the total energy use of the house by its total floor area. The result is a comparable unit which does not correlate with the efficient use of space and might actually encourage to build bigger buildings in which the lower energy consumption per square meter is often easier to achieve than in small buildings. Unnecessary large buildings have higher energy and resource usage than smaller buildings despite the fact that they could have better energy efficiency rate.




*Form factors of different one storey buildings. Form factors in the upper row are calculated by dividing the building envelope by the building volume. In the lower row the divisor is the usable area. Source: Lylykangas, 2016.*

# Materials, technology and building techniques

The building phase has the largest impact on energy and resource use as well as greenhouse gas emissions. In comprehensive and detail plans the possibilities for good construction are created but lots of important decisions are still left to the developer and the architect. This chapter introduces ways to minimize non-renewable and toxic resource usage and promotes better construction techniques that for example create longer lifespan for buildings.

## Ground and foundation techniques

Ground conditions on the site can have a significant effect on the CO2 emissions of the entire building project. Both the choices of materials and foundation techniques have an impact on total emissions. For example the CO2 emissions caused by pile-driving in a clay ground were 41 % of the total construction and material emissions in Suurpelto day care center According to VTT sustainable building case study (Vares, Häkkinen, Shemeikka 2011, 46).

## Material emissions & stored carbon

A significant part of the emissions of the built environment are produced in the construction phase and by manufacturing building materials. Extracting different materials has very different environmental impacts from oil drilling to heavy mining. Also, many materials require huge amounts of energy in their manufacturing processes.

A good way to validate material choices is to calculate carbon footprint for a building material and thus compare the impact of different structures. Calculating the required material volumes and then using the emission factors of different materials is a rather simple way of getting a grip of the advantages and disadvantages of different materials.

*In Helsinki, VTT Technical Research Centre of Finland has researched the carbon dioxide emissions of different materials by building two identical multi-storey houses, one with concrete frame and th other with wooden frame. The wooden house had 75 % smaller carbon footprint than the concrete house. (Loukkaanhuhta, 2017) Picture: Press photo by Markku Rantala, Yle, Finland*



| | Eco-house | | Standard passive house | | Common Finnish one family house | |
|---|---|---|---|---|---|---|
| | kg CO2e | CO2 / m² | kg CO2e | CO2 / m² | kg CO2e | CO2 / m² |
| Roof | 1085 | 10 | 1426 | 13 | 1026 | 9 |
| Exterior walls | 1110 | 10 | 11283 | 103 | 1675 | 15 |
| Windows | 1411 | 13 | 1411 | 13 | 962 | 9 |
| Intermediate floor | 216 | 2 | 6509 | 59 | 216 | 2 |
| Partition walls | 855 | 8 | 1100 | 10 | 855 | 8 |
| Base floor | 537 | 5 | 3312 | 30 | 5335 | 49 |
| Foundations, cellar | 520 | 5 | 4930 | 45 | 4930 | 45 |
| Chimney, natrual ventilation pipes | 2574 | 23 | 663 | 6 | 663 | 32 |
| House technique | 377 | 3 | 1014 | 9 | 1014 | 1 |
| Others | 579 | 3 | 847 | 5 | 797 | 5 |
| **Total emissions** | **9264** | **84** | **32496** | **295** | **17474** | **159** |
| Carbon storage | 21791 | | 2562 | | 11170 | |
| Balanced emissions | -12528 | | 29934 | | 6303 | |

*Hänninen calculated the total material emissions for his plan of a 120 m² one family house using existing structures of three different Finnish one family houses. The first from the left is Rannanpientalo in central Finland (eco-house), in the middle standard passive house in southern Finland and on the right common Finnish one family house from 2016. The passive house had a much larger carbon footprint than the standard or eco-house. In the eco-house the stored carbon exceeds its material emissions. Source: Hänninen, 2016.*

In his master's thesis Hänninen (2016, p. 49) calculated building and material emissions of his 120 m² one family house with different structure types. He used the materials of a common Finnish one family house, a passive house and an eco-house and compared them with each other. The materials of the passive house had over three times larger carbon footprint than the materials of the eco-house. The difference between them was the equivalent to 35 years of heating emissions in a house with geothermal heating and solar panels.

Many renewable materials, like wood, store carbon with photosynthesis when they grow. When these materials are used in construction, the carbon stored in them exits the natural carbon cycle and stays outside for as long as the building is standing. Therefore, it is possible to calculate a carbon storage value for wooden buildings and subtract that from the material emissions. In a massive wood house the stored carbon can be equivalent to the emissions of heating the house for a decade (Hänninen 2016, p. 48).

It is, however, important to notice that smaller carbon footprint is not necessarily equal to a more sustainable end result. Material emission calculations make difference only if the basic factors like usage of renewable materials are taken into account. In his master's thesis Mattila (2014, 51) shows how looking only at the emissions of materials can mislead us to use non-renewable materials over renewable ones. In the example, lighter plastic insulation material had smaller carbon footprint than denser and heavier cellulose fibre.

| Material | CO2 emissions g CO2e / kg | CO2 emissions kg CO2e / m³ | CO2 storage g CO2e / m³ |
|---|---|---|---|
| Aluminium profile | 3640 | 9828 | |
| Mineral wool | 990 | 148,5 | |
| Roof plates | 880 | 6908 | |
| Welded steel beam | 780 | 6123 | |
| Glass | 660 | 1650 | |
| Glue laminated timber | 330 | 145,2 | 768 |
| Burnt clay brick | 220 | 286 | |
| Concrete | 200 | 480 | |
| Eco wool | 180 | 7,2 | |
| Plastering clay | 130 | 234 | |
| Timber | 70 | 33,6 | 768 |

*Examples of carbon dioxide emissions and carbon storages of different materials. The column on the left represents the materials' emissions per kilogram and the middle column shows their emissions per cubic metre. Differences between materials are significant. Source: Nissinen & Rantala, SYNERGIA material emission tool instructions*

*Using recycled materials or surplus materials like straw can lower the carbon footprint of a house. Pictures: Ben Graham, Green Building Advisor*

*Massive wood like CLT stores carbon. Picture: Press photo by Yle, Finland*

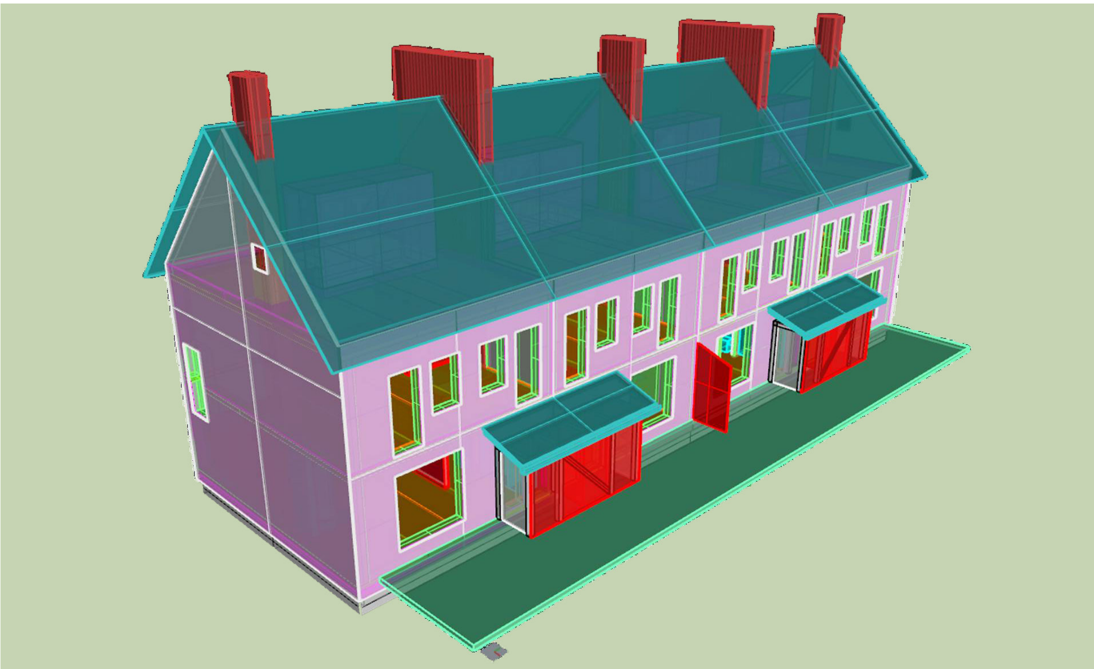
## Use of renewable and non-renewable materials

According to Holger Wallbaum (2017) the building industry uses 50 % of raw materials and causes 60 % of land harvesting globally. Because of the massive resource usage we can make enormous difference with our choices of materials.

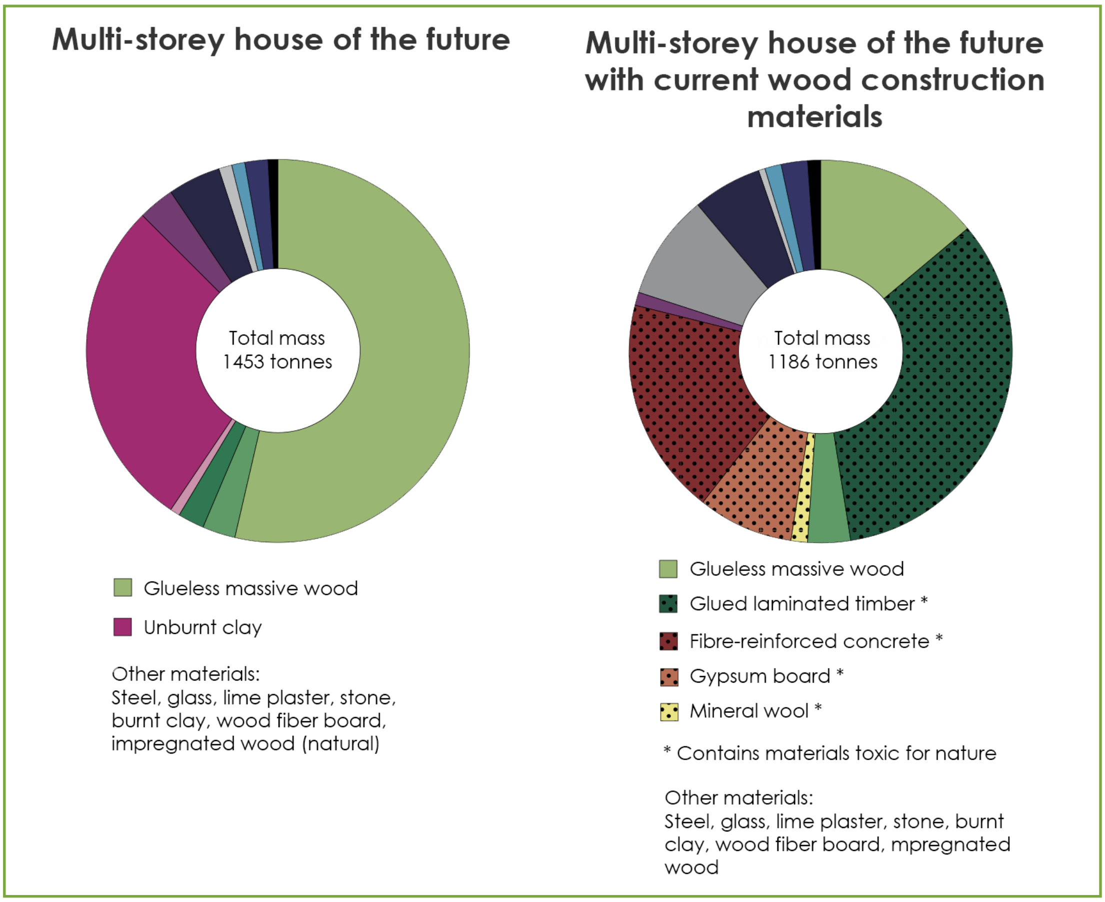
Since the beginning of the industrial revolution our entire economy and therefore also the building industry have been based on the usage of non-renewable materials and energy sources. We as a human race know that we are overusing natural resources and fossil fuels but we are avoiding the confrontation of the problem. Non-renewable resources are, like their name implies, limited. Sooner or later we will run out of them. Therefore, to build in a truly sustainable way it is really hard to justify the usage of any of these materials.

With our current building standards it would be nearly impossible to avoid certain non-renewable materials. There are lots of researches and new experimental projects that try to find ways to avoid the usage of non-renewable materials. In his master's thesis Löfroos (2013, 49) has limited the use of these materials very carefully in his definition of an ecologically sustainable house. Löfroos says that non-renewable materials may be used only if the material is possible to reus or return to manufacturing without quality losses.

Mattila (2014, 10) says that the idea of a closed material circulation is a beautiful thought but not a realistic one. No matter how carefully we plan the circulation there is always a small amount of materials escaping the planned material flow. That is why Mattila suggests us to use only the materials that are not toxic or harmful if they end up in nature. In his plan of a multi-storey house of the future he refuses to use materials like plastics (pvc, polystyrene), concrete, glue laminated wood, oil and acrylic paints and composite materials.



*Architecture office Livady is planning a house that has no harmful materials like plastics or concrete. The basic structure is of massive wood and the chimneys for natural ventilation are made of burnt bricks. Picture: Architecture office Livady, 2017.*




*Material comparison between Mattila's Multi-storey house of the future and standard Finnish wooden multi-storey house. According to Mattila, we should stop using toxic and harmful building materials. Source: Mattila 2014 p. 50.*

*Woodcube is designed by a German architectural office, Architekturagentur, in 2013. It is based on Holz100 -massive wood elements that are totally glueless as well as metal and plastic free. Source: Arch Daily, Pictures: Martin Kunze*

## Lifespan and technology dependency

The economics of the building industry, like many other industries, is based on the growth of consumption. Since the birth of element building techniques our way of construction has moved towards shorter building lifespans. New houses are not expected to last for generations but they are planned to last a certain amount of time, usually 50 years, and to be replaced after that. In Finland the one family house has an average lifespan of only 64 years. A good example of this disposable building culture is J-P Ristmeri's century house project (Granath 2016) in Finland. He wanted to build a house to last for at least a century, but when he called all Finnish package-house factories, none of them promised their house to last for that long.

According to Mattila (2014; 11, 15) the current building legislation leads us to use complicated structures that are impossible to maintain by their user. Our buildings are becoming more complicated technologically. The functionality of today's multi-level structures is hard to estimate in the long term use, and the structures are impossible to repair or replace without deconstructing the entire structure. In addition, these solutions are very vulnerable to building errors and failures of technical equipment during power outages.

In their master's theses both Mattila (2014) and Hänninen (2016) emphasize the use of natural low tech building techniques like natural ventilation and simpler structures. Mattila promotes the use of glueless massive wood and traditional log building techniques. Also Ristimeri (Granath 2016) uses simple structures in his attempt to build a house to last for a century.

*Old log houses have lasted much longer than modern houses are planned to last. Simple structure makes them easy to maintain or even move to another location if needed. Picture: Pasi Peiponen, Yle*

# Energy

Energy production is the largest emitter globally. Most of our enormous energy needs are fulfilled by burning different things, mostly fossil fuels. To maintain our civilization we need to find ways to lower our energy needs and to produce energy with less resources and emissions.

Orust has its own very ambitious goal of becoming energy neutral before 2020. Orust considers energy neutrality as a mean to be self-sufficient with energy production. This could be achieved in electricity production with significant investments, but without total change in infrastructure and transportation habits abandonment of oil and other export fuels will be difficult. This paper concentrates on low emission energy production in buildings in newly developed areas instead of trying to solve energy production questions of existing infrastructure.

Energy is linked to our capacity to store it and the emissions and resource use when producing it. This chapter covers ways to cut down energy usage in buildings and how to produce energy in a rural environment.

## Energy efficiency

To be able to cut down emissions and non-renewable resource usage we need to be more efficient with our energy use, but energy efficiency has to have a goal or otherwise it will not serve any purpose. That has happened already in many industries including the building industry. According to Larsson (2017), Sweden's emissions have not declined although the energy efficiency has nearly doubled in 20 years. This shows exactly what we as humans have done since we learned how to sow: Increased efficiency gives us tools and a reason to produce more instead of decreasing. How many car factories plan their assembly lines to be more efficient to be able to sell less cars?

It is naive to think that we can solve our problems with emissions by making things more efficient. Energy efficiency serves a purpose but it has to be linked straight to emissions or resource use. We need to stop seeing energy efficiency values and U-values as an indicator of sustainable development.

We currently measure the energy efficiency of buildings by the energy needed to warm a square meter. Finland's energy certificate takes into account the used energy per area (kWh/m$^2$) and multiplies it by emission factors. To calculate emission factors is a good start but currently our way of measuring energy efficiency does not encourage us to aim for a lower total energy consumption. In larger buildings it is easier to get smaller energy efficiency rating. Hänninen (2016, 40) says that our living space has doubled since 1970 even though our energy efficiency per area has increased.

So instead of only concentrating on making things more efficient we should seek for means to use less. Our living, transportation and consumption habits have to change radically to allow cutting down our energy demand. We need to adopt a culture where we find meaning in our lives without the need of consuming more. Even now the studies indicate that there is no link between happiness and greenhouse gas emissions (Larsson 2017).

In the future we should examine total emissions of a building during its entire lifespan. In this kind of calculation we quickly see that the energy consumption plays a much smaller role than our choice for energy source. We should also monitor the means to greater energy efficiency. Building more complex structures that need fixing or replacing and using more materials we could cause more emissions than we save during the entire lifespan of a building. Therefore, energy efficiency should be achieved with simple maintainable structures and technical solutions.

## Energy production

The way we produce our energy is critical from the point of view of material usage and emissions. Different production methods work in rural context and in the city.

When distances between households grow larger, the energy losses and required infrastructure to move hot water or electricity from a power plant to each house grow. At the same time the system becomes more inefficient, expensive and vulnerable. That is why decentralized energy production has many benefits in rural context.

Decentralized energy production means that each household or community produces the energy they need instead of buying it from elsewhere. Producing energy locally can reduce the need for heavy infrastructure and it makes energy distribution networks more resilient to errors. Energy saving in households becomes much more concrete when energy is produced by its users.

In their research about designing rural eco-districts Nysted, Sepponen and Virtanen (2012, 29-34) compare the benefits and disbenefits of off-grid solutions. Off-grid means that the local network or individual houses are separated from the municipal network. According to the research, separation needs to be planned carefully and matters like energy storage need to be taken care of. Research says that regardless of grid system, the possibilities of local production should be investigated.

| Power type | g CO2e / kWh |
|---|---|
| Electricity (Swedish average) | 128 |
| Wood, pellet | 30-100 |
| Solar heat | 20 |
| Solar electricity | 40 |
| Wind power | 20 |

*Energy production emissions by source. Table: Electricity emission by European Environment Agency, other emissions by Hänninen, 2016. Picture: Kaija Kervinen, Yle*

| Electricity source | TWh (2014) | % of total |
| --- | --- | --- |
| Hydro power | 64,2 | 42% |
| Wind power | 11,5 | 8% |
| Nuclear power | 62,2 | 41% |
| Solar power | 0,08 | 0,06% |
| Other thermal energy | 13,3 | 9% |
| *CHP, industry* | *5,9* | *4%* |
| *CHP, district heating* | *6,9* | *5%* |
| *Conventional power* | *0,5* | .. |
| *Gas turbines etc.* | *0,01* | .. |
| **Total** | **151,2** | **100%** |

*Electricity production distribution by energy source in Sweden in 2014. Source: Byman, 2016*

**These renewable heating and electricity production methods should be considered when building ecological rural districts.**
(Comparison: Nysted, Sepponen, Virtanen 2012, p. 34)

**Geothermal or ground heating** is an efficient and cheap way to produce heat in rural area. Ground heat requires area so it is not as effective in dense areas. It also requires ground with enough moisture to be able to conduct the warmth. Drilling a hole into bedrock is more expensive and it is not allowed in groundwater areas. The strength of geo-warmth is that the system works during day and night year round.

**Burning wood or pellet** is very popular in rural areas like Orust. It is considered cleaner than burning fossil fuels but it actually creates a lot of small particle emissions as well as carbon dioxide emissions. Fireplace or boiler is still an effective back up heating system.

**Solar heat and electricity** are clean during usage but require an unshaded site. Solar PVs (photovoltaic panels that produce electricity) require pi and other minerals, so from the point of resource usage it is not as clean as solar heat that uses simpler technology. Prizes for solar systems are declining. In Sweden the solar energy is efficient only from spring to autumn, so the system needs to be combined with another heating system.

**Wind power** is a clean way of producing energy but it requires large investments and a good place to be productive. The weakness of wind power is its inconsistency: power is created only when it is windy.

**Air heating** is a very cheap and simple method to supplement other heating systems. They are rarely powerful enough to be the only heating method. Air heating systems do not have a very long lifespan so from the resource point of view it is not the most ecological solution.

**Electrical heating** with water circulation or electrical radiators is an efficient heating method. In Sweden, where the average electricity has a small carbon footprint, electrical heating is rather clean. It could significantly cut emissions in areas where a lot of wood is burned.

# Food production and local agriculture

More important than the actual area for farming is the way we use our arable land. Local agriculture is a way to cut down emissions caused by transportation and to make a place more self-sufficient. According to Larsson (2017) the emissions caused by food production for an average citizen of Gothenburg are 1,3 t $CO_2e$, one fifth of the total emissions. Especially animal production has a significantly large carbon and ecological footprint. Globally 25 % of all land is used for animal pasture or animal fodder production (Climate guide 2010). Agriculture is also one of the main reasons for cutting down forests and rainforests globally.

There are still lots of possibilities in agriculture if we take ecological values into account more thoroughly. We can move from damaging processes to regenerative processes where instead of lowering the impact of human actions we generate more than we consume. This chapter introduces an idea of carbon smart agriculture and permaculture as ways of future food production.

## Carbon smart agriculture

The large amount of emissions caused by agriculture comes from the energy used for actual farming and animal care. Ruminants like cows and sheep also produce significant amounts of methane (Climate guide 2010). Changes in land use are also a huge factor. Farmlands are typically emitters themselves, and the fields are usually created by cutting down the forests that function as carbon sinks.

To change this agriculture needs to shift from carbon sources into carbon sink. According to Tuomas Mattila (2017) this can be done simply by minimizing the time the farmland is without vegetation. Plants used during off season need to be able to both sequester carbon from the air and store it in the ground for longer periods of time. For example rye is this kind of a collector plant. In addition to environmental benefits this also raises the productivity of the field.

*At Kilpelä's organic ranch in southern Finland fields have vegetation during off season as well. Maintainig vegetation on fields transforms them from carbon sources into carbon sinks. Picture: Press photo, magazine Maaseudun tulevaisuus.*

*Mark Shepard's 100-acre permaculture farm. Picture: Permaculture Apprentice*

## Permaculture

Permaculture is a sustainable way of increasing the productivity of farmlands. The basic idea behind permaculture farming is to turn agriculture into a circular and regenerative process instead of a wearing process. A permaculture farm does not concentrate on producing only one or two species of plants, but it mixes as many as possible. This is a way of mimicking natural environments where different types of plants live in the same area. With permaculture the productivity of a certain area can be increased. The larger biodiversity also reduces erosion and strengthens the farm's resilience towards changes in environment. Rotational cropping can also increase productivity of farmland.

Permaculture farm in temperate climates like in Sweden is a mosaic of fields, forests, hedgerows and orchards. Treelines and fields need to be orientated in a way in which the trees shade the fields as little as possible. In Sweden's latitudes where sun shines from low angles especially the southern slopes are very good places for permaculture farms. Permaculture farm is also arranged so that the most labour intensive plants are grown nearest to the dwellings. (Millison, 2016)

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# Principles for ecological planning in rural context

## Typology and building patterns

**Land use changes**
Avoid building on naturally delicate land or on land that has forest or other natural carbon sinks. Do as little changes on natural state of site as possible and try to increase its biodiversity rahter than limit it. (page 12)

**Building density**
Build as dense as possible but make sure that each building receives sunlight to reduce the need for heating. *(page 13)*

**Building orientation**
Orientate buildings so that the longer edge faces south to take advantage of passive solar energy. *(page 14)*

**Building shape and volume**
Design houses with as few corners as possible. Compare different building shapes by using form factors. (page 16)

## Materials, technology and building techniques

**Ground conditions**
Check the ground conditions on site. If possible, found buildings without piling or heavy foundations and do not build cellars. *(page 17)*

**Material source**
Make a comparison between use of renewable and non-renewable materials. Avoid all materials that you would not throw into nature. *If they are not healthy for nature, how could they be healthy for humans? (page 20-21)*

**Material emissions**
Use materials with small carbon footprint or carbon storage capabilities. Make calculation of emissions of the main structures. *(page 17-19)*

**Building techniques**
Use simple and easily maintained solutions. Make sure materials and layers are repairable and easy to separate from one another. Always consider total lifespan of a certain solution. *(page 22)*

## Energy

**Energy efficiency**
Limit unnecessary energy usage with passive and active methods like using proper insulation or building smaller houses. Instead of calculating U-values or energy usage per square meter always measure the total consumption. *(page 23-24)*

**Energy production**
Concentrate rather on energy source than energy efficiency. Measure different energy solutions by their emissions instead of actual energy usage. *(page 24-25)*

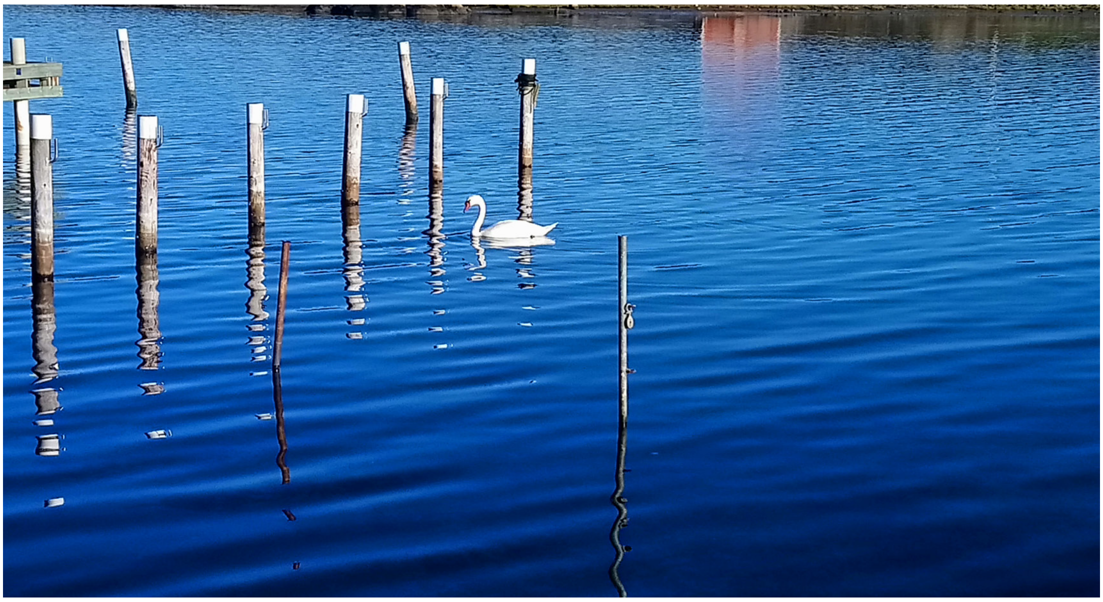
## Food production and local agriculture

**Carbon smart agriculture**
Turn fields into carbon sinks by having vegetation on them all year round. Use collector plants that can store carbon into the ground. *(page 26)*

**Diverse farmlands**
Mix different species on fields to make farms more resilient. Adapt rotational cropping with mixture of species to increase productivity of arable land. *(page 27)*

Part 2:

# Plan for new Dalby village



## Planning an eco-village on Orust

Orust has ambitiously set the goal for the municipality to be "climate and energy neutral in 2020". Climate and energy neutrality are abstract concepts and hard to measure. This paper and the plan for New Dalby village values different planning solutions with the tools described on pages 8 and 9. For the actual village plan in Dalby the new and more precise objectives were set.

The New Dalby village plan is a concept plan for the specific location but the ideas behind the plan can be implemented on different sites either on Orust or in other rural areas in nordic climate. More than architectural design it is a tool to describe the focus points that can actually make a great difference.

The plan starts with an analysis that specifies area microclimate and natural conditions as well as the current land use and building stock. After the analysis the plan is presented using the same structure that the theory part has. All planning solutions are justified with calculation or theories described on the first chapter. The map of the site can be found with the summary of the plan on pages 48 and 49.

### Objectives for the New Dalby village

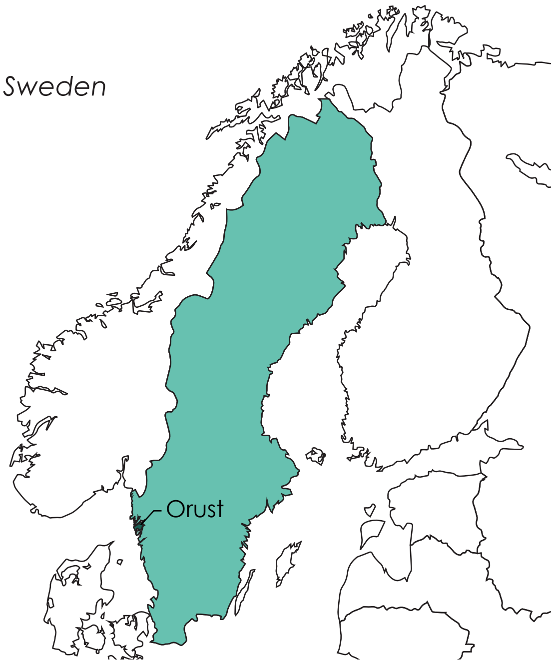
- All building frames and structures last at least for a hundred years.
- The future emission targets for housing (cutting down 80% of $CO_2e$) are met.
- Carbon stored in structures is larger than emissions caused making them.
- Materials used are natural and local.
- Safe and traditional building solutions grant functionality in all conditions.
- Life in the village without your own car is practical.
- Significant percentage of the food eaten in the village is locally produced.
- Heating energy and electricity used in the village are produced there.
- The village offers also reasonably priced high quality rental housing.

# Dalby - Site analysis

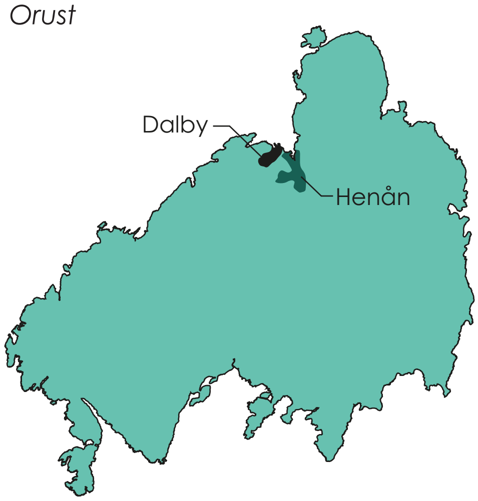
The site for New Dalby village is on the west side of Henån, approximately two kilometers from its center. The size of the site is approximately 27 hectares. Currently the area is used for farming and as a pasture for animals. There are a couple of one family houses around the fields. The planning site lies in between steep rocky hills on both east and west side of the site. The sea lies also very close and the shore protection area starts directly from the northern border of the site.

The site has a lot of potential for an eco-village because its closeness to Henån makes it possible to live in Dalby without owning a car. The orientation of hills and flat area offer good ground for local agriculture. There are no forests on site so no cutting is needed when constructing new buildings.

*Sweden*




*Orust*



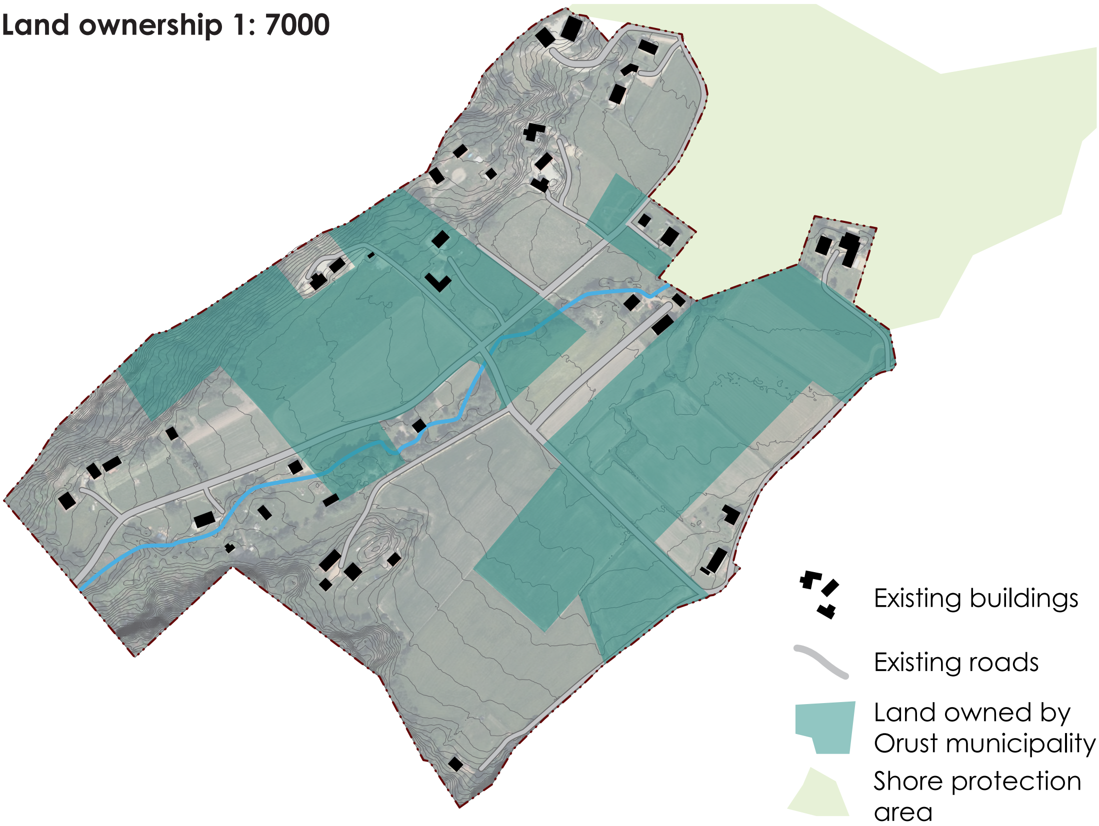

*Dalby site 1:10 000*

## Land use & land ownership

The land used for agriculture is mostly owned by Orust municipality and it is rented for farmers to use. Therefore it is easier to plan and control the development of New Dalby village. Arable land is used for growing crops and also grass for animals. Housing is mainly located near hills on the western and eastern sides of the site.

**Conclusion:** The easiest way to control the building process is to build on municipal land. To leave the maximum amount of land for cultivation the recommended place for settlements is on the western side of the site.

**Land ownership 1: 7000**




*Most of the land on Dalby site is currently used for agriculture.*

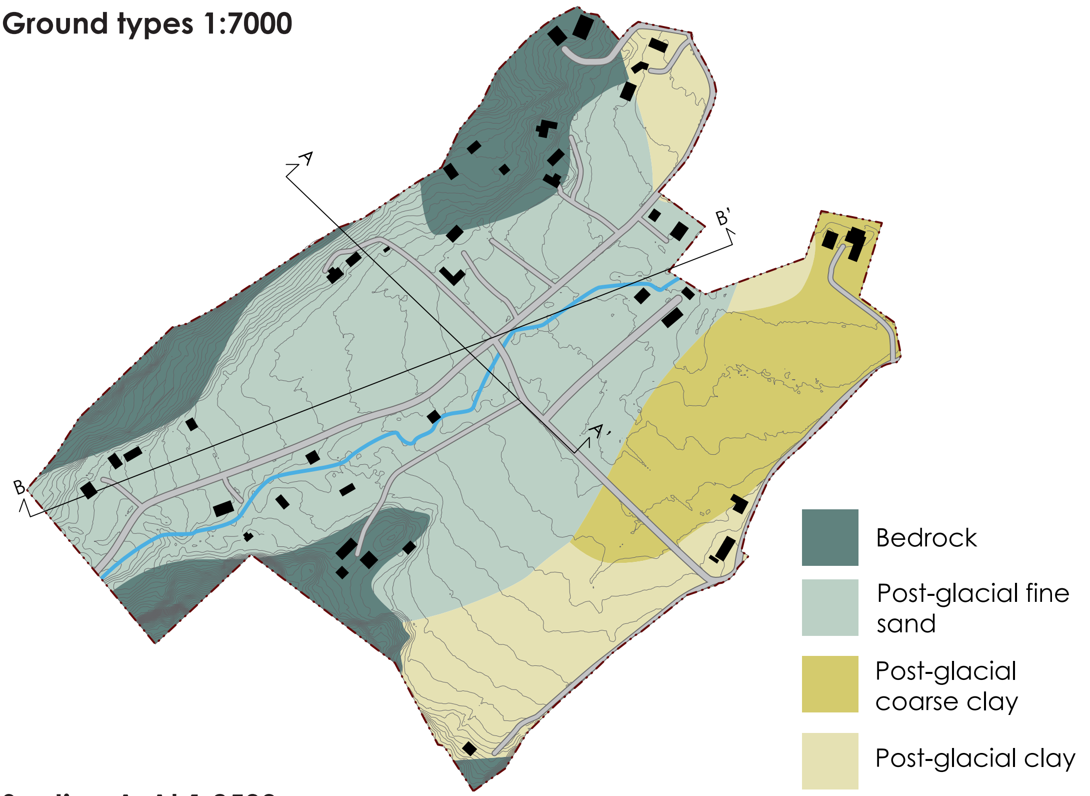
## Typology & ground type

The site is a plain between rocky hills. On hillsides the bedrock is seen but the arable land is mainly fine sand. On eastern part of the site there are clay areas as well. Bedrock close to surface and fine sand are good materials for founding buildings because no piles are needed and the ground takes loads very well. Lighter foundations lower $CO_2$ emissions and expenses.

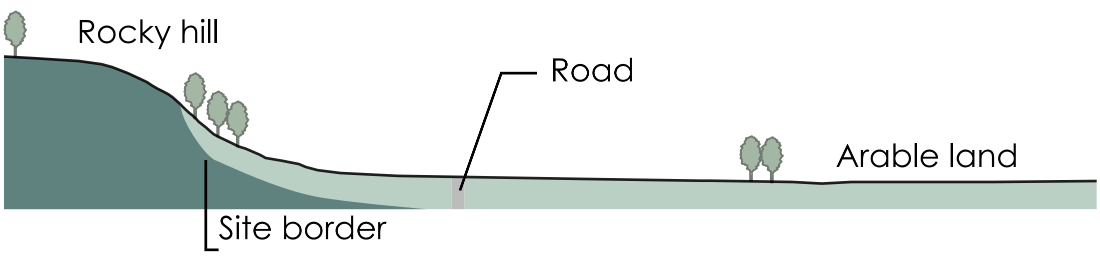
All slopes dip towards the sea but despite the flatness of arable land it is covered from most of the floods since it is at least 6 meters above sea level. A small ditch runs through the site towards the sea as well.

**Conclusion:** The best ground types to build are on the western side of the site. Clay on the east makes foundations much more difficult and expensive.

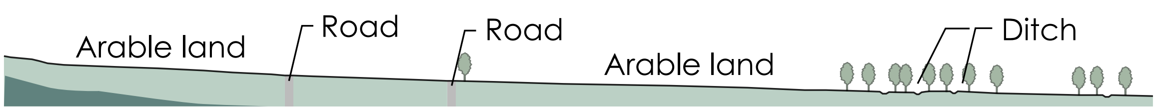
### Ground types 1:7000




### Section A-A' 1:2500




### Section B-B' 1:4000



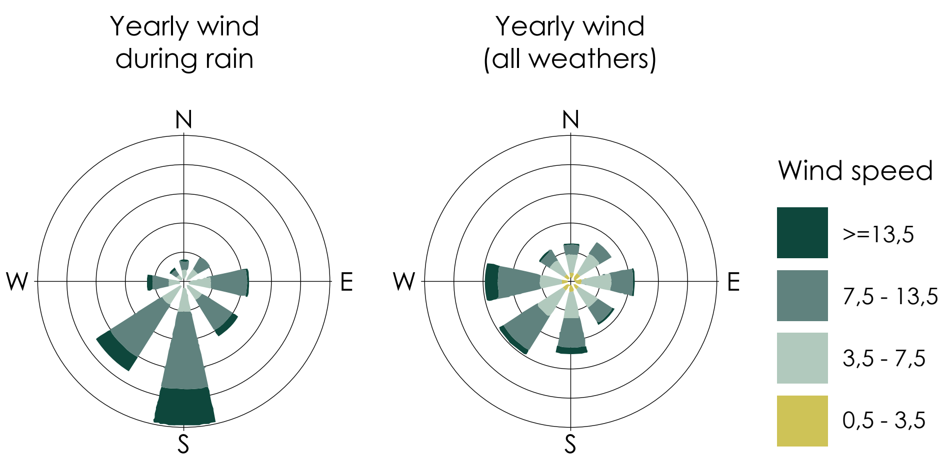
## Climate conditions

Climate conditions in Dalby are good for eco-village. On the west coast of Sweden the wind blows mostly from west and south-west. Because Dalby is in the northern part the island blocks most of the wind from that direction. Hills around the site can also help block the unwanted wind.

During summertime Dalby gets a lot of sunlight and sun rises up to 57°. From spring to autumn the solar panels are an effective way to produce electricity and service water. During winter months the sun barely rises above horizon and the day length is only 6 hours. Solar energy cannot be made profitable even with good placement.

**Conclusion:** The best place to build is in the northern part of the site. There is nothing to block the sunlight and because of the slope towards the south the houses can be placed in denser formation.

**Yearly wind speeds and direction**




*Source: Swedish Hydrological and Meteorological Institute (SHMI)*

| | Sunrise | Sunset | Daylength | Solar noon |
|---|---|---|---|---|
| Spring equinox - 20.3. | 06:13 → 89° | 18:26 ← 272° | 12:12 | 12:19 32° |
| Midsummer - 21.6. | 04:11 ↗ 40° | 22:16 ↖ 320° | 18:05 | 13:13 56° |
| Autumn equinox - 22.9. | 06:57 → 88° | 19:11 ← 271° | 12:14 | 13:04 32° |
| Winter solstice - 21.12. | 08:54 ↘ 136° | 15:26 ↙ 224° | 06:32 | 12:10 9° |

*Source: Time and Date association*

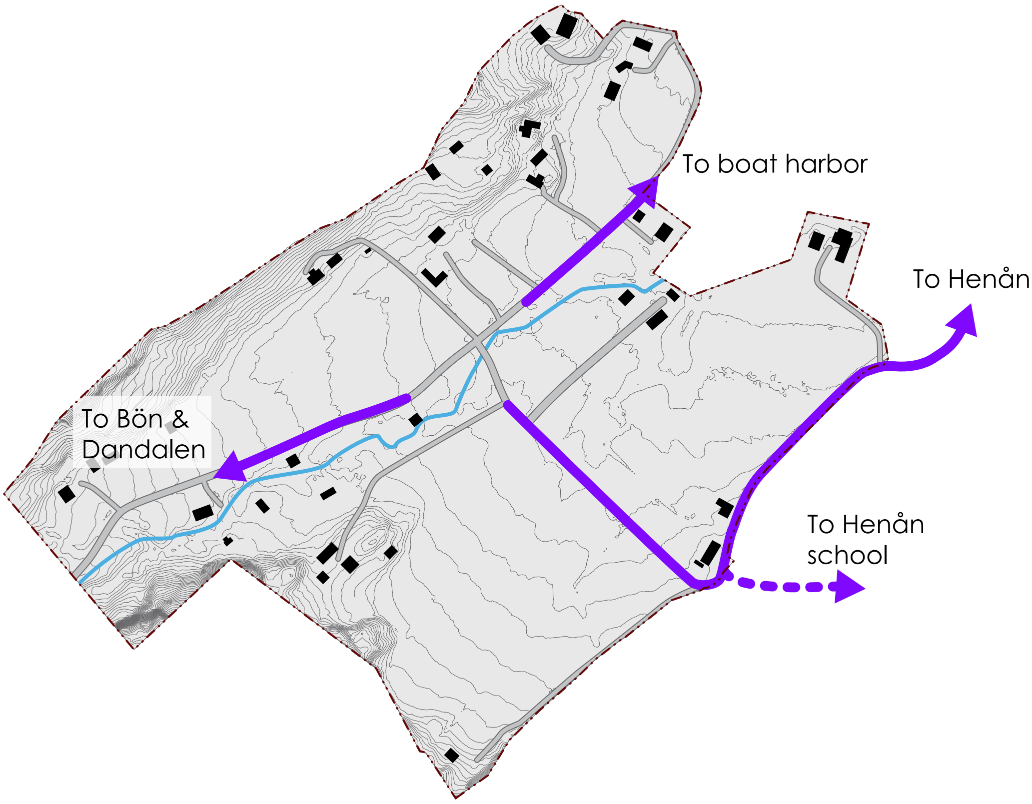
## Transportation

The closeness to Henån makes moving from New Dalby village to services very easy. The site lies approximately two kilometers from Henån and by walking it is possible to take a shortcut to Henån school and industrial area.

The roads on the site are rather narrow and do not encourage to ride a bike or to walk. Because of the current road layout the north-east part of the site is much furher away from Henån than the parts on the southern side of that field.

**Conclusion:** The most ecological place from transportations point of view is the eastern part closest to Henån.

**Routes to different destinations 1:7000**




**Travel times to the closest services**

| Destination | Car | Bicycle | Walking |
|---|---|---|---|
| Henån center grocery | **5 min**<br>2,0 km<br>0,32 kg CO2e | **9 min**<br>2,0 km<br>0 kg CO2e | **25 min**<br>2,0 km<br>0 kg CO2e |
| Henån school | **8 min**<br>2,5 km<br>0,43 kg CO2e | **12 min**<br>2,5 km<br>0 kg CO2e | **22 min**<br>1,8 km<br>0 kg CO2e |

*Travel times: Google maps*

## Existing buildings

Existing buildings are mainly villas and barns with one or two storeys. Appearance and age of different houses varies a lot.

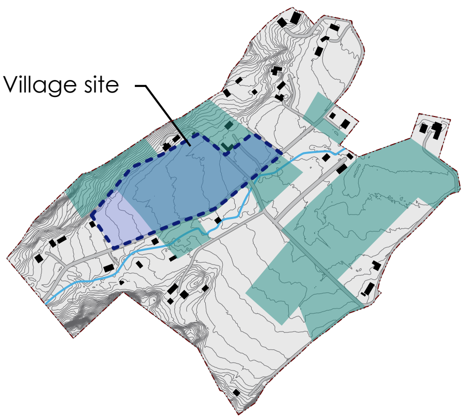
# Buildings and placement

According to the analysis, the best place to locate the village is on the northern slope of the site. Ground and microclimate conditions are the best and the land is mainly owned by the municipality. To preserve as much arable land as possible, and to strengthen social contacts, the village is built on a relatively small area.

The basic idea behind the current layout is to maximise sunlight and save land for gardening and local agriculture. Buildings are set up in four groups that formulate small hubs. In the middle of each hub there is a pond to gather rainwater and around it there is room for outside activities and playgrounds.

Between these hubs there are lots of trees and places for gardening and small scale food production. Diverse nature can surround the houses and continue even under them. The goal is to make as little impact on ecosystems as possible. All parking spaces are along the road and moving inside the village happens by foot or bike.

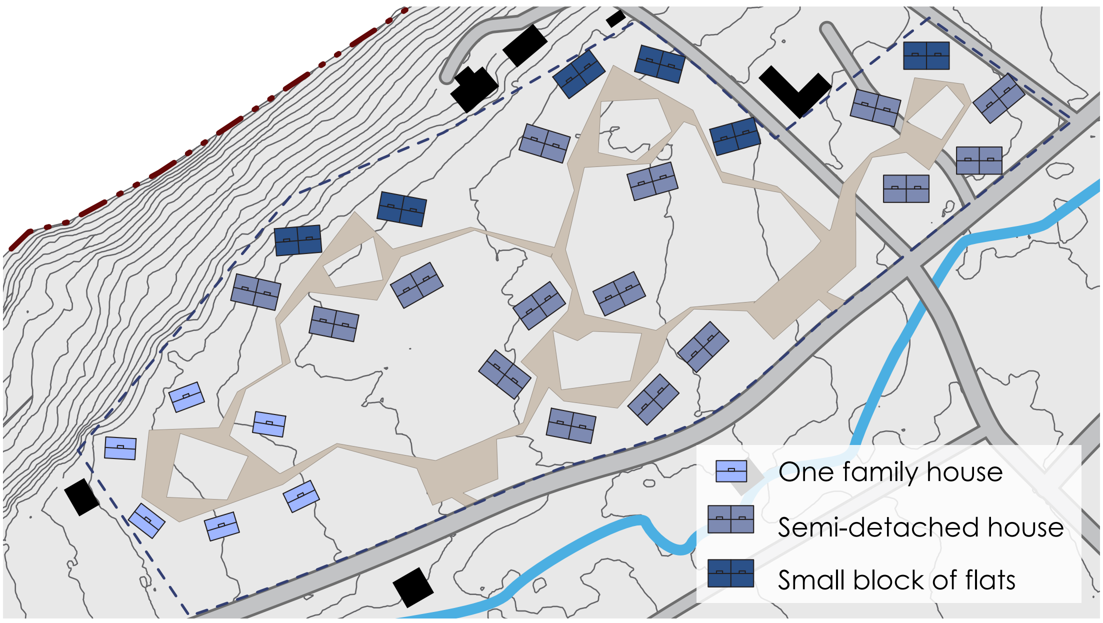
One goal of the New Dalby village is to mix both owner occupied houses with apartments with rental apartments. The village consists of one family houses, semi-detached houses and small blocks of flats that mimic the existing building typology on Orust in a modern way.




| House type | Number of houses | Apartments per type |
|---|---|---|
| One family house | 6 | 6 |
| Semi-detached house | 15 | 30 |
| Small block of flats | 6 | 24 |
| **Total** | **27** | **60** |

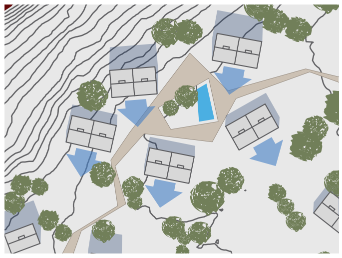
*The amount and distribution of different house and apartment types.*

**Building placement in the village 1:2500**



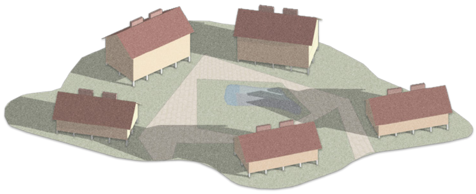
### All buildings receive sunlight

*Houses are orientated so that they receive a maximum amount of sunlight year round. To maximize solar energy production and insolation energy the long wall of each house is facing south with a maximum tilt of 40°. Windows face mainly south with the same ratio or area as in the solar house example on page 15.*

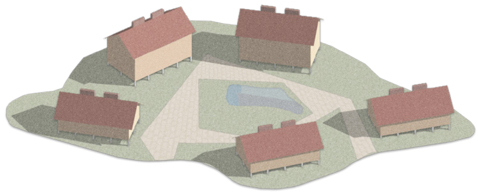


*Most of the windows are on southern facade.*

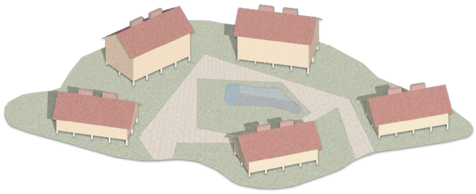
### Shadow study of a hub



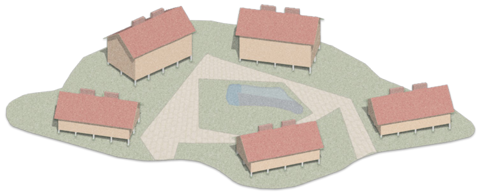
*Spring (and autumn) equinox 08:00*



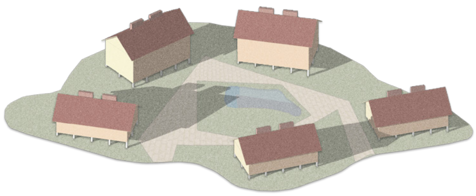
*Midsummer 08:00*



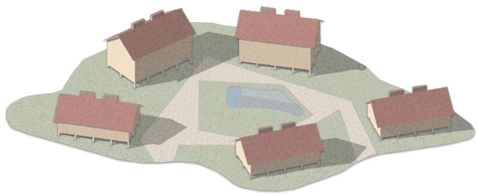
*Spring (and autumn) equinox 12:00*



*Midsummer 12:00*



*Spring (and autumn) equinox 16:00*



*Midsummer 16:00*

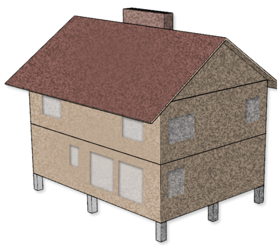
### Illustration of a hub

# Standardized houses

To be able to calculate the impact caused to nature the planning is done with three standard houses. Because the goal is to build both owner-occupied houses and rentals the New Dalby village has both traditional one family houses and apartments. To match existing building scale of the Henån area the maximum height of all houses is two floors. To keep the greenhouse gas emissions on a reasonable level the living areas are kept reasonable even in villas.

The buildings in the New Dalby village are designed to last for at least a century but if they are maintained correctly they can last much longer than that. To guarantee long lifespan all houses are extremely simple in structure and therefore easy to maintain and repair. Houses do not depend on any electrical equipment to stay healthy.

Each building works with natural ventilation. Long chimneys and high attics ensure the required pressure difference that is needed for natural ventilation. Steep roof keeps structures dry and snowless and offers good angle for solar panels. Each house is founded on pillars to make the base floor wooden and to keep it dry in all conditions.



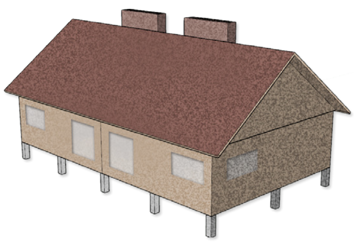
**One family house**

Floors: 2

Livable area: 110 m² / apartment

Apartments: 1

Measures: W 9 m / L 7 m / H 10 m



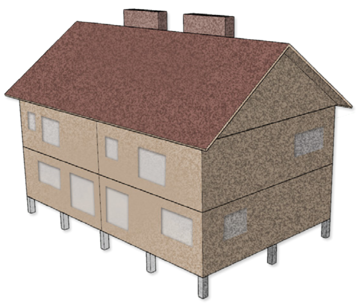
**Semi-detached house**

Floors: 1

Livable area: 54 m² / apartment (total 108 m²)

Apartments: 2

Measures: W 15 m / L 9 m / H 8 m



**Small block of flats**

Floors: 2

Livable area: 54 m² / apartment (total 216 m²)

Apartments: 4

Measures: W 9 m / L 15 m / H 10,5 m

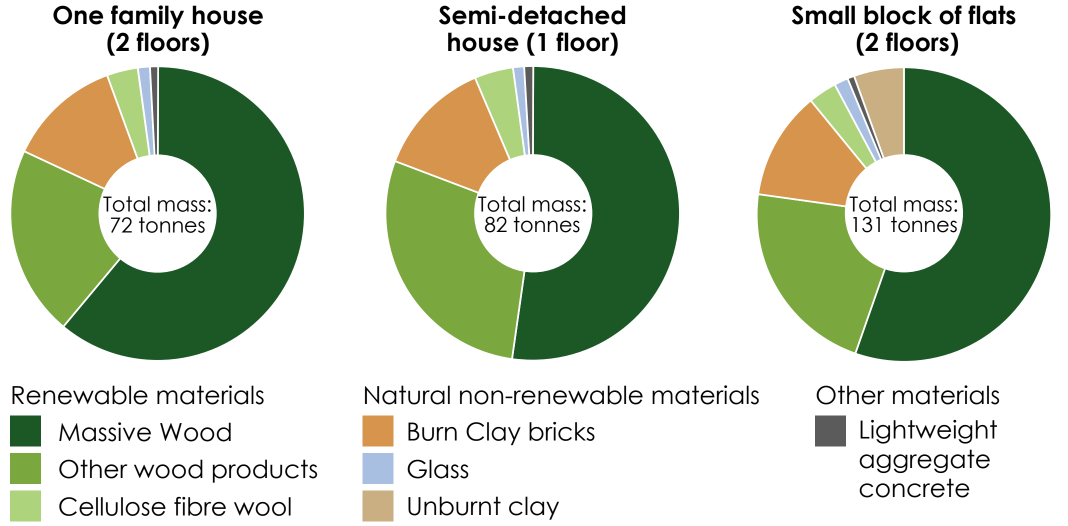
# Materials

New Dalby village uses renewable or natural and non-toxic materials. The only exception to this is the foundations that are pillars made of blocks of light-weight aggregate concrete (see the material palette below). The walls are made of glueless massive wood and insulated with cellulose fibre wool (structure section on the right). All intermediate and base floors are made of glueless massive wood as well. In the small block of flats the soundproof and burn refractory are handled with a layer of unburnt clay.

*Structure section of the exterior walls.*

Material CO2e emissions are slightly larger than emissions of the example eco-house on page 18. This is mainly because in Dalby the structures are so much more massive than in the eco-house. Total material usage is larger than in a normal one family house but more than 80 % of all used materials are renewable. The amount of carbon stored in structures is nearly ten times larger than in the example eco-house. In all houses the stored carbon is approximately seven times more than the material emissions.

**Material palettes of each builfing type**




| | One family house (2 floors) | | Semi-detached house (1 floor) | | Small block of flats (2 floors) | |
|---|---|---|---|---|---|---|
| | kg CO2e | CO2 / m² | kg CO2e | CO2 / m² | kg CO2e | CO2 / m² |
| Roof | 2 337 | 21 | 4 843 | 45 | 4 843 | 22 |
| Exterior walls | 5 165 | 47 | 4 042 | 37 | 7 425 | 34 |
| Windows | 1 361 | 12 | 1 411 | 13 | 2 822 | 13 |
| Intermediate floor | 1 024 | 9 | 0 | 0 | 2 306 | 11 |
| Partition walls | 1 714 | 16 | 1 152 | 11 | 2 304 | 11 |
| Base floor | 1 169 | 11 | 2 423 | 22 | 2 423 | 11 |
| Foundations | 187 | 2 | 249 | 2 | 249 | 1 |
| Chimney, natrual ventilation pipes | 1 227 | 11 | 753 | 7 | 1 840 | 9 |
| House technique | 100 | 1 | 120 | 1 | 240 | 1 |
| **Total emissions** | **14 284** | **130** | **14 993** | **295** | **24 453** | **159** |
| Carbon storage | 96 174 | | 109 004 | | 164 679 | |
| Balanced emissions | -81 890 | | -94 011 | | -140 226 | |

*Material emissions and stored carbon for each house type.*

# Energy solutions

Energy consumption is often considered to measure whether a house is ecological or not. In the New Dalby village, energy consumptions are not compared. Instead, the focus is on the emissions caused by the energy production.. Basic structures and volumes of each house type are used to calculate consumption for each house and this is multiplied by emissions of each energy source (Table on page 24).

Sweden's electricity production emissions are relatively small because of the huge amount of nuclear and hydro power. Despite this, greenhouse gas emissions can be cut down significantly by producing energy and heating service water with solar panels. The emissions caused by building solar panels are included on their production as well as the need to replace them a couple of times during the building's lifespan.

Energy emission comparison is done with three different methods that are available and suitable in Dalby area: electric and geothermal heating and burning wood. The comparison (below) shows how self-provided electricity production combined with geothermal energy has the lowest carbon footprint. The site in Dalby is on fine sand so the pipes for geothermal power are easy and cheap to install.

New Dalby village uses geothermal power combined with solar panels on the roofs. The roof area is not filled with solar panels, so more panels can be added later.

| | **One family house** | | **Semi-detached house** | | **Small block of flats** | |
|---|---|---|---|---|---|---|
| | kg CO2e / house, year | kg CO2e / resident, year | kg CO2e / house, year | kg CO2e / resident, year | kg CO2e / house, year | kg CO2e / resident, year |
| **Electric heating** | 2380 | 793 | 2568 | 642 | 4786 | 598 |
| + Solar heating panel | 1898 | 633 | 2111 | 528 | 4147 | 518 |
| + Solar PV | 974 | 325 | 1856 | 464 | 3838 | 480 |
| **Geothermal heating** | 1070 | 357 | 1138 | 285 | 2189 | 274 |
| + Solar heating panel | 898 | 299 | 972 | 243 | 1958 | 245 |
| + Solar PV | 735 | **245** | 718 | **180** | 1649 | **206** |
| **Burning wood*** | 1559 | 520 | 1689 | 422 | 3142 | 393 |
| + Solar heating panel | 1262 | 421 | 1394 | 349 | 2743 | 343 |
| + Solar PV | 966 | 322 | 959 | 240 | 1761 | 220 |

*According to Hänninen (2016) the emissions for burning wood are 30-100 g CO2e /kWh so this calculation uses its average 65 g CO2e / kWh.*

*Emission comparison for energy production for each building type with three different energy sources available on site in Dalby, with and without solar energy solutions. Solar heating panels produce nearly all hot service water in three buildings and solar PVs (p. 25) produce electricity to cut down the amount of bought in energy. Sizes of solar panels are in the table below. Calculation is done by using Jarek Kurnitski's calculation tool designed to calculate the energy consumption of one family house.*

| | One family house | Semi-detached house | Small block of flats |
|---|---|---|---|
| **Southern roof** | 56 m² | 102 m² | 102 m² |
| **Solar heating panels** | 12 m² | 12 m² | 16 m² |
| **Solar PV** | 18 m² | 28 m² | 34 m² |
| **Roof area with panels** | 54% | 39% | 49% |

# Total carbon footprint of housing

The New Dalby village has an extremely low carbon footprint due to its ecological material and energy solutions. Because of the used calculation tools these CO2 emission comparisons do not include the energy savings created by consistent use of solar energy. According to Lylykangas (2014) these can be up to 22 % of annual heating energy usage in a normally insulated house. New Dalby village's closeness to Henån makes a very low-carbon lifestyle possible since it is possible to live in the village without owning own car.

Total housing emissions for a New Dalby village dweller are 241 kg CO2e per year. This is calculated using a lifespan expectancy of 100 years. Houses are not depending on any technological equipment and they are easily kept dry so the actual lifespan can be much longer than the 100 years.

Because of the usage of huge massive wood elements the structure's carbon storage is significant. If the total carbon storage is divided annually in a time period of 100 years, it will still be greater than the annual total emissions of one family house and semi-detached house.

**Total CO2e emissions for different house types**

| | One family house | | Semi-detached house | | Small block of flats | |
|---|---|---|---|---|---|---|
| | kg CO2e / house, year | kg CO2e / resident, year | kg CO2e / house, year | kg CO2e / resident, year | kg CO2e / house, year | kg CO2e / resident, year |
| Building and material emissions | 143 | 48 | 150 | 37 | 245 | 31 |
| Energy production (Geothermal + solar heat & electricity) | 735 | 245 | 718 | 180 | 1649 | 206 |
| Demolition phase | 28 | 9 | 27 | 7 | 34 | 4 |
| **Total emissions** | 906 | **302** | 895 | **224** | 1928 | **241** |
| **Total carbon storage** | 962 | 321 | 1090 | 273 | 1647 | 206 |

*Because of the extremely low carbon dioxide emissions of the building materials in New Dalby village, the materials have a much smaller role than the energy production during the 100-year lifespan. If we manage to stop using fossil and non-renewable fuels the energy production emissions per year will drop during house's lifespan. One more reason to concentrate on building materials is the fact that their emissions are produced now when fossil fuels are still used for most material production processes.*

**Emissions caused by housing (all combined)**

New Dalby village:
**241**
kg CO2e / resident per year

Average Finland:
**2730**
kg CO2e / resident per year

*Source : Suomen ympäristön mittarit 2011, Finnish Environment Institute*

**Emissions caused by housing energy use and production**

New Dalby village:
**199**
kg CO2e / resident per year

Average Sweden:
**1580**
kg CO2e / resident per year

*Source: Evaluating Sweden's emissions: at home and abroad, Stockholm Environment institute*

# Local agriculture

Fields around the New Dalby village are used for local food production. Ideas of carbon smart agriculture and permaculture are applied and most of the arable land is preserved. The loss of field under the new village are compensated with more productive farming methods.

Gardens in the village are used for small scale food production and all trees produce fruits and nuts for the people. Leaf trees in the village are used to shade houses during summer. The most labour intensive plants are grown in the village near houses and larger scale production is done on the fields.

The slope dipping toward south is used to grant lots of sun to all plants in and around the village. Gardens in the village collect rainwater into small pools, and the water is then used to water plants.

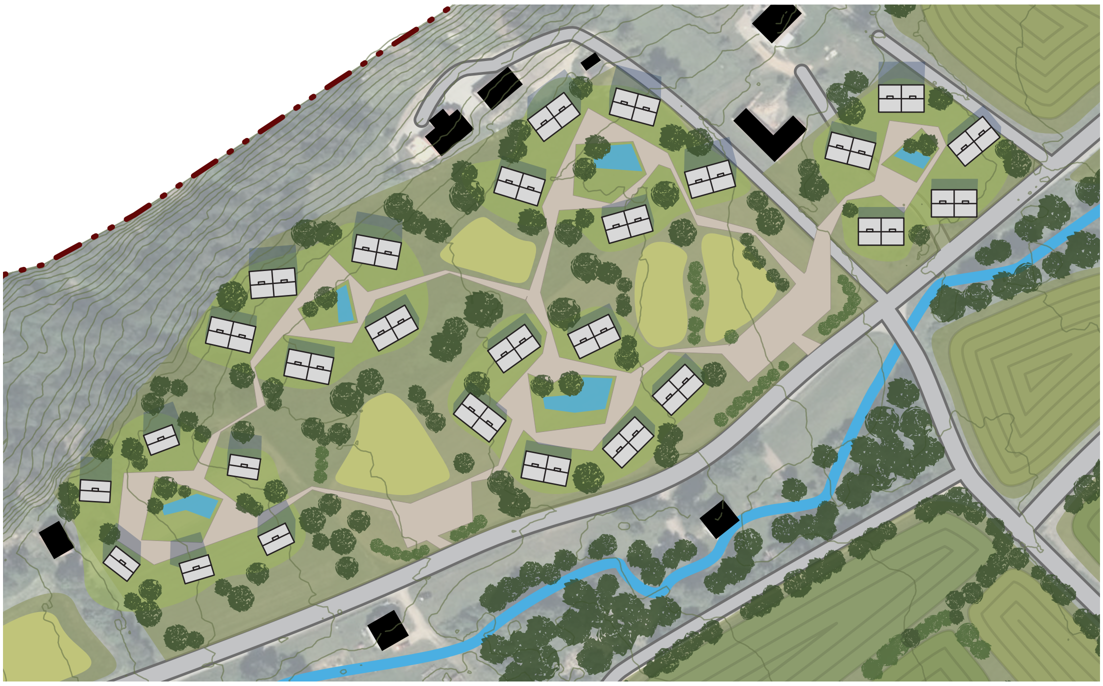
The fields are divided to smaller sections and rows of productive trees and bushes to bring diversity and reduce erosion. Treelines are planned to grant as much sunlight to the fields as possible.

The fields have vegetation on them all year round turning them into carbon sinks. The ditch is surrounded by trees and bushes to prevent nutrients entering the sea.

*Fields are located on the southern side of the site.*

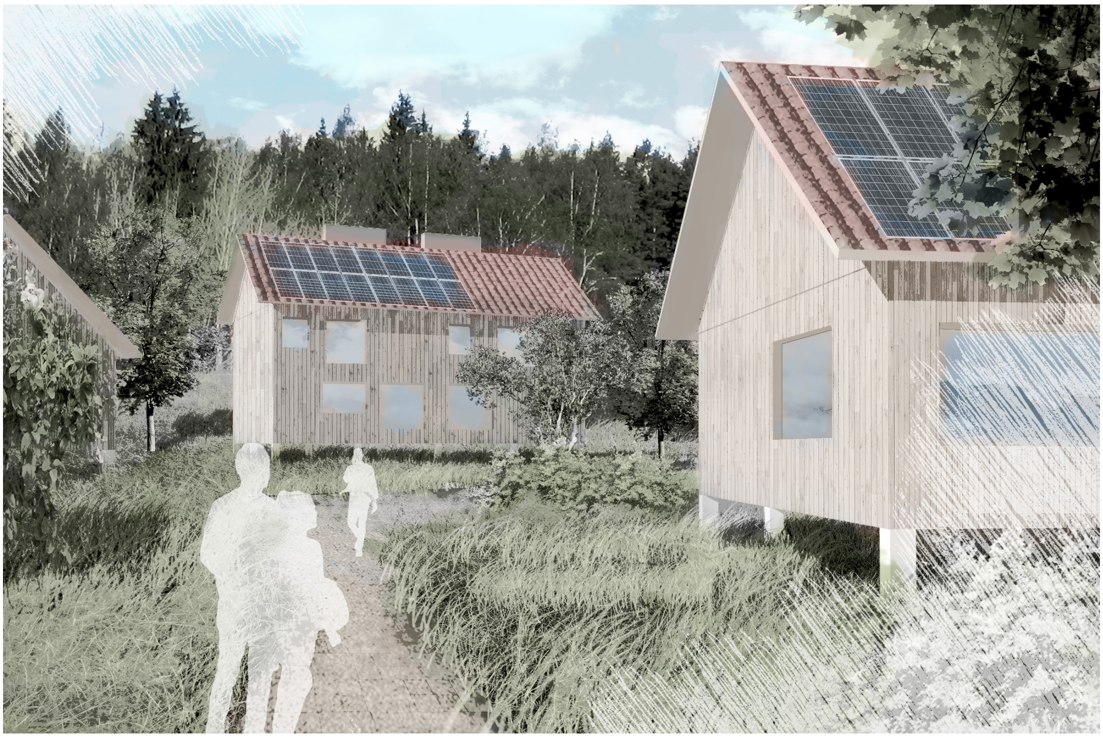
*Instead of growing grass the fields are used for more natural and effective local food production.*

**Local farming in the village 1:2500**



**New Dalby field layout 1:5000**

# Plan for New Dalby village 1:2000



## New Dalby village - Summary

New Dalby village is an ambitious eco-village plan. The plan combines technologies and planning methods of both future and past to lower the impact caused to nature. New Dalby village has a significantly lower carbon footprint and harmful material usage than average housing today. It creates possibilities for truly sustainable lifestyle.

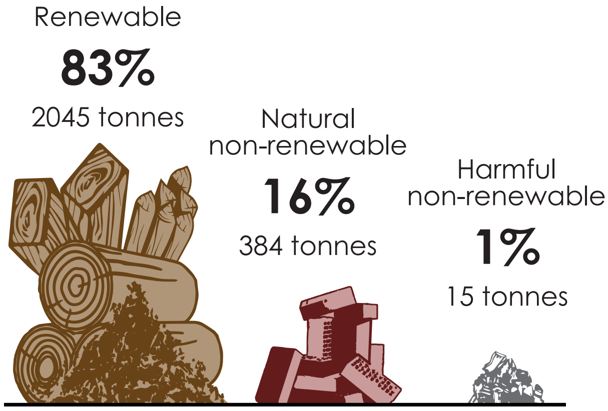
### Basic facts

- New Dalby site: **27 hectares**
- Village site: **3 hectars**
- Arable land: **11 hectars +** gardens in the village
- New buildings in the village: **27**
- Apartments: **60**
- New inhabitants: **126**

| House type | Number of houses |
|---|---|
| One family house | 6 |
| Semi-detached house | 15 |
| Small block of flats | 6 |
| **Total** | **27** |

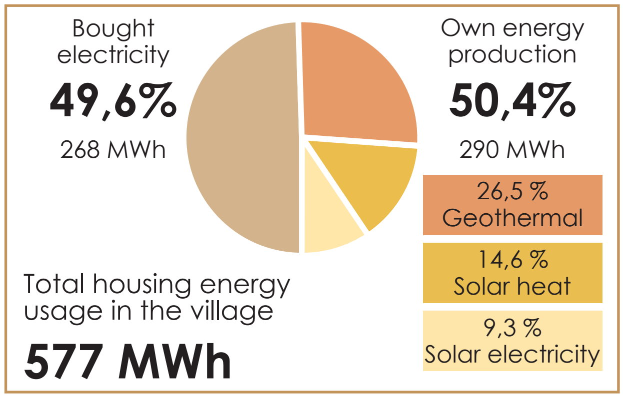
## Material usage

New Dalby village uses renewable or natural and non-toxic materials. The walls are made of glueless massive wood and insulated with cellulose fibre wool. Foundations are made of pillars made of blocks of lightweight concrete. Lightweight concrete and solar PVs on rooftops are the only things containing harmful, non-natural materials but their amount is very small.




## Energy solutions

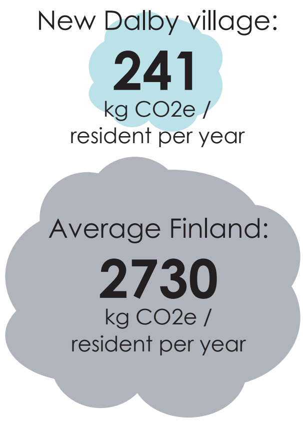
All houses in the New Dalby village use geothermal power combined with own solar panels. Bought electricity is renewable and the use of geothermal heat cuts down emissions and grants better functionality in all weather conditions than solar or wind power.



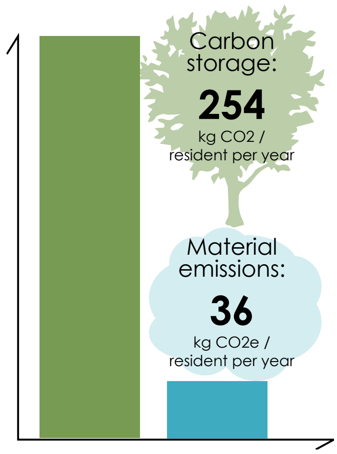

## Carbon dioxide emissions

The New Dalby village has extremely low carbon footprint due to its ecological material and energy solutions. Because of the usage of huge massive wood elements the structure's carbon storage is significant. New Dalby village's closeness to Henån makes a very low-carbon lifestyle possible since it is possible to live in the village without owning a car.

**Emissions caused by housing**
*Materials + building + energy use + demolition*




**Material usage emissions compared to carbon storage**



CHALMERS
ARKITEKTURSKOLA

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Designstudio Planering och gestaltning för hållbar utveckling i lokalsamhället:
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Designstudio del B / Fördjupningsprojekt
Tuomas Ranta-aho