NTNU
Norwegian University of Science and Technology

Assignment 3

Integrated Energy Design

AAR4926

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Contents

1 Introduction

This project is small Camphill Community with people who have special needs, situated on the old Rotvoll esate, right at the edge of the fjord, 10 minutes drive east of the city of Trondheim.

Latitude: 63.438460 N

Longitude: 10.485125 E

2 Background

Functional programme

The project should include area for:

Fram school

* Work rooms for skills development and production

* Multifunctional hall (sports, concert, etc.) must accommodate 50 to 100 people.

* Lecture rom, library, computer room.

* Exhibition space

* Offices

Residential

* 2 extended family houses for one couple and 2 volunteers and 6 students in each family.

* Small apartments with an alcove, bathroom and a single kitchen for users (30) and staff.

* Rooms for the common dining, kitchen and lunch with large fireplace.

Public interface

* Café

* Concert hall

* Exhibition, conference space

3 Design Progress

The first step in the design process is to focus on minimising the energy need.

The second step is about covering the building's energy need through the use of as much sustainable energy as possible. In terms of design, it means focusing on e.g.:

• Using free solar heat supplements for heating

• Prioritizing low temperature heating like floor heating, which can be combined with solar heat

• Examining the possibilities for using biomass boilers

• Designing for the use of active solar heat and solar cell systems

Third step is about efficient use of fossil fuels to cover the remaining energy demands in the building. This is done in the design process by ensuring:

• An efficient energy supply

• Adjusting for the actual operating profile of the building

• Dividing into zones of similar functions and needs, which can be supplied from the same unit

3.1 Available Energy Sources

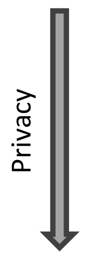
Electrical Grid: readily available but limiting electrical consumption must be a priority.
District heating: infrastructure is being developed and use may be compulsory
Bio-mass: wood from on-site forest for heating is sensible and almost carbon neutral. Also being an operational farm with likely expansion in future Bio digester for methane gas production must be further explored.
Solar: possibilities of making use of direct gain, indirect gain (solar thermal, thermal mass) and PV. Although PV has cost ramifications. Lack of sun in winter is also an issue.
Wind: turbines are an option as wind and elevated locations on the south hill are available. Cost may be a mitigating factor.
Heat Pump: ground source (aprox 5°C) as well as water body (fjord) (temp ?) are available.
Animal Heat: using animals as a heat source was a common technique in the past but is it a realistic solution today? (Typical cow produces 1500 W/h)

4 Proposal

The guiding design feature of our proposal centres around a common zone that acts as a link between all the spaces and functions, provides vertical and horizontal circulation, acts as social zone, is a sun space and interface between inside and outside, and climatic and energy device.

Vertically special planning divided in to :

Ground floor: public interface, offices, work rooms



First floor: residential (house and flats), library, lecture and computer room

Loft: residential (house and flats), communal facilities (kitchen, lunch and dinning)

5 Energy Strategies

5.1 Passive strategies

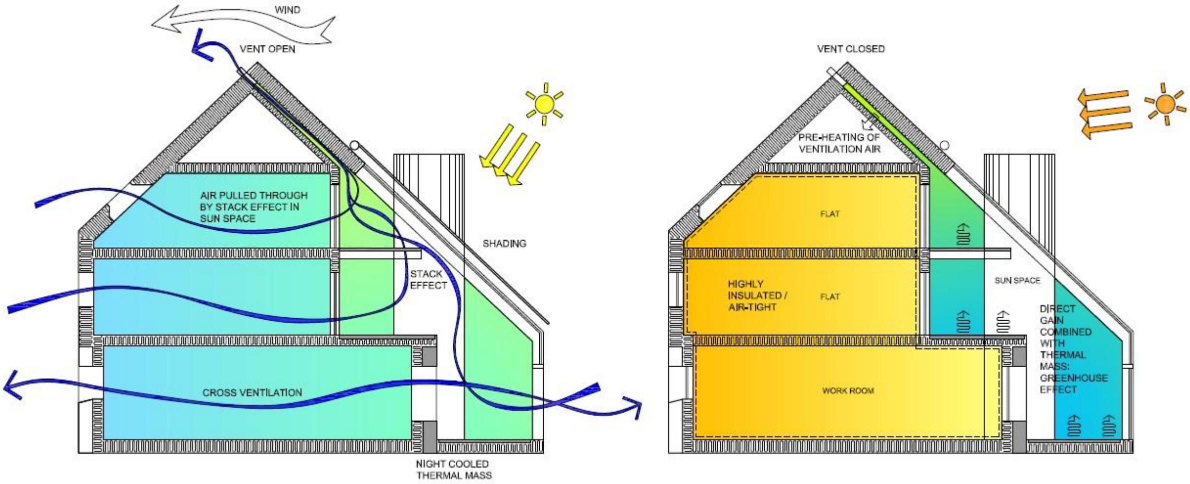


Fig 1. Passive strategies cooling & heating

Passive cooling

Shading, natural ventilation and thermal mass are employed in the passive cooling strategy of the design.

The retractable shading device (Conservatory awning W8 from Warema) is extended over the glazed roof elements of the sun space to prevent direct gain.

Opening the fenestration of the sun space on ground level allows for cross ventilation when other ground level windows / doors are opened. Cooling breezes result.

Opening external as well as sun space facing openings on the upper levels promotes the stack effect for natural cooling and hot air exhaust ventilation: As the hot air rises in the sun space and wind over the roof creates a negative pressure the open rotary vent in the roof apex allows for a natural stack effect, drawing cooling air through the living and working spaces.

Clear story windows of sun space on ground floor level are meant to stay open at night to allow adequate night flush ventilation of the thermal mass which can then absorb the heat of the following day.

Passive heating

strategies concerning this emphasise heat retention and direct gain combined with thermal mass and greenhouse effect.

preventing heat loss of living / working spaces through high levels of insulation and air-tight construction are important heat conserving measures.

Large glazing of south facing sun space maximizes direct solar gain. Thermal mass in sun space absorbs, stores, and releases radiation from direct gain. This results in a 'greenhouse' effect in the sun space with long wave radiation being trapped in the glazed area. Heated thermal mass also provides thermal inertia to the space.

The sun space thus acts as a buffer between inside and outside, an intermediate space. It provides pre-heated air which is then intended for the ventilation system. And this is where the passive strategy meets the active system.

5.2 Active strategies

Service modules

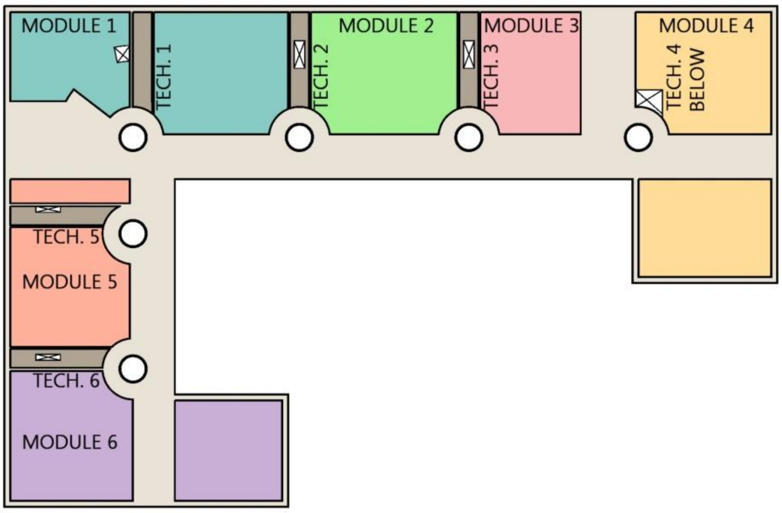


Fig 2. showing 'service modules' (heated zones(colour)). The grey sunspace is a non-heated zone.

A prominent feature of the design are the thermal water storage tanks located at regular intervals within the sun space. Each tank corresponds to a technical room located on ground level or basement level as in module 4. Each tech. room also contains a vertical services shaft for distribution.

The result is: ‘service modules’ consisting of the spaces adjacent and above. This system allows for a decentralized approach allowing for more demand governed service provision as well as reducing piping / ducting distances. This all results in energy reduction.

With regard to heating and ventilation services each module has: large thermal accumulator or buffer tank, wood pellet boiler, air handling unit, and an allocation of solar thermal collectors on roof. All equipment can thus be sized according to its ‘service module’ demand.

Heating & ventilation system:

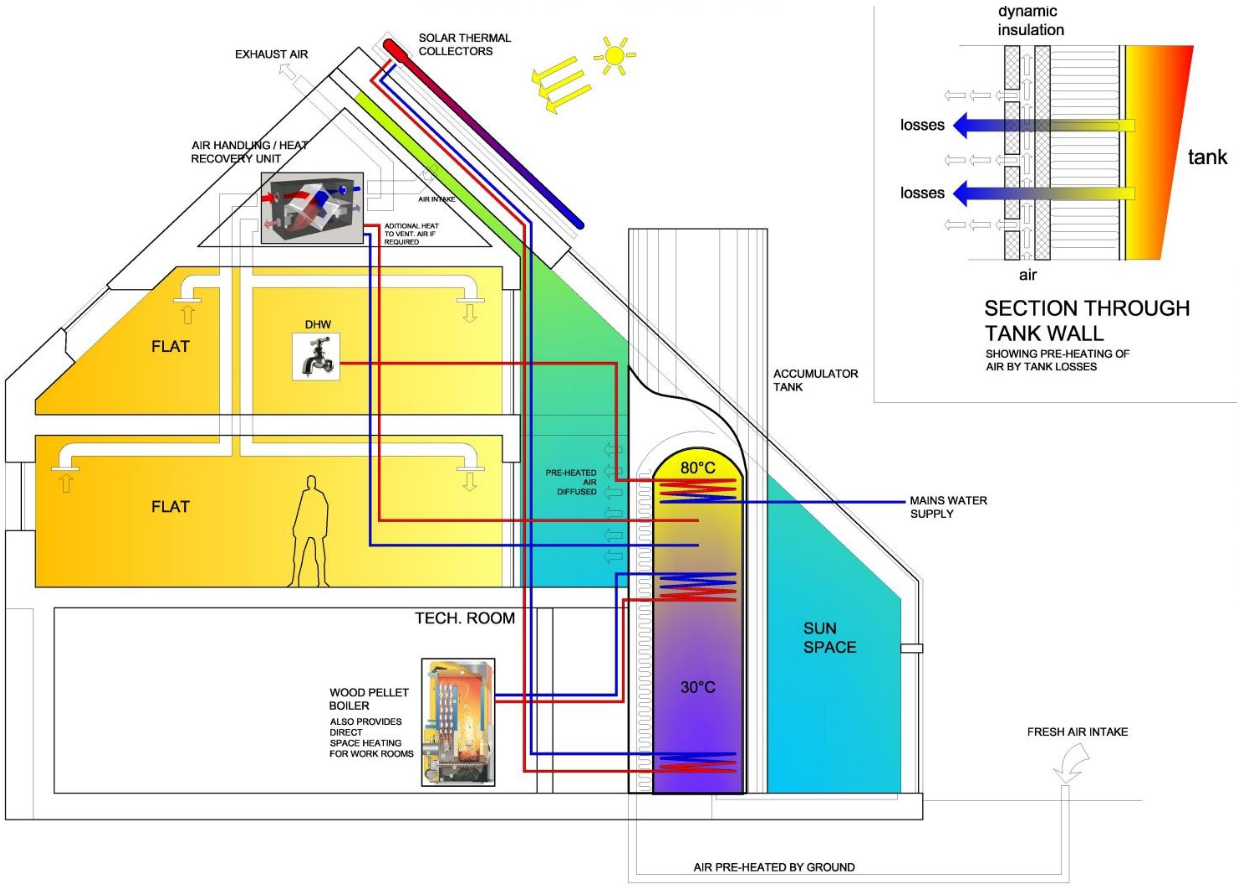


Fig 3. Heating and vent system for one ‘services module’

The tank

The thermal storage tanks act as conventional accumulator tanks but are sized larger ($50m^3$) than is usual to allow for thermal energy to be stored for longer periods.

Thermal inputs

1. Solar thermal collectors: take care of hot water needs during the sunny months (see fig 6) the large tank allows for the accumulation of the solar energy when it is available storing it for when there might be periods of cloud etc.

2. Wood pellet boilers: back up the solar thermal ensuring that the tank does not drop below the desired temp. This will likely be the primary heat source in winter. These boilers also provide direct space heating to the adjoining work rooms. If the work rooms are used a lot and require the corresponding increase in fire place (boiler) space heating the tank will store the excess energy generated for later use.

Thermal draws

1. DHW, this coil will be located at the top and hottest point of tank. Hot water can thus be supplied at mains pressure.
2. hydronic heating: this is fed to the air handling unit to boost the ventilation air temp if required.

Ventilation system

The ventilation system is somewhat unconventional. It is designed in this way to: 1] save energy by making use of pre-heated air in the ventilation system and 2] achieve more favourable conditions in the sun space / winter garden during the colder periods.

The system:

Fresh outside air is drawn into ducts which lead to below the tanks underground. The air is thus pre heated by the ground (we can assume approx. 5 degree ground temp in Trondheim).

The ducts emerge below the tanks insulation layer. This layer consists of 300mm conventional insulation for internal skin and 100mm dynamic insulation for the outside skin (see *fig 3*).

The air is lead into the dynamic insulation (ENRGYFLO).

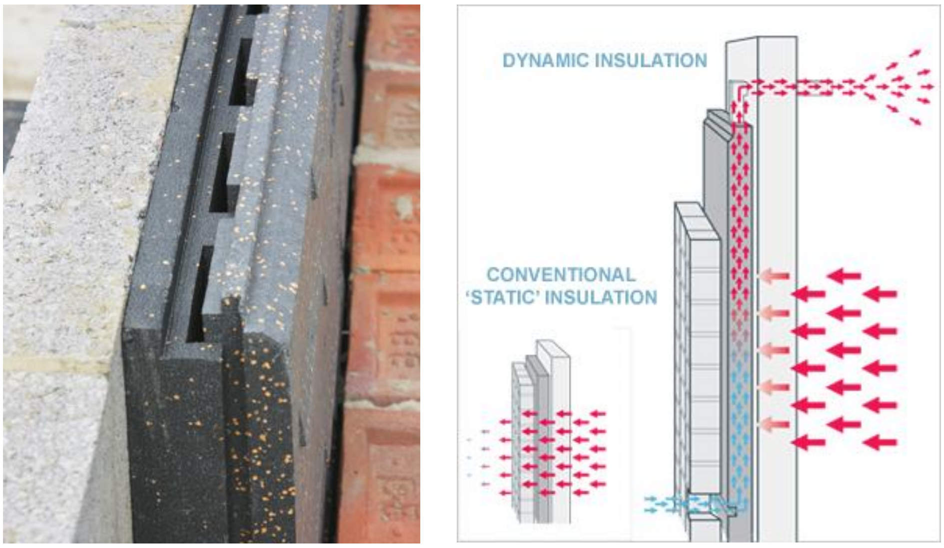


Fig 4. Energyflo dynamic insulation

As it moves up the inside of the insulation it gets heated further by the tanks natural thermal losses at the higher levels of the tank and at higher temp the insulation would be punctured and the now warmer air is diffused into the sun space where it will rise further to the roof apex to be drawn into the air handling and heat recovery unit.

By making use of the losses of the tanks the temp inside the sun space (particularly around the tanks) will become tempered and a pleasant 'winter garden' is created. Also the air is now pre-heated before it enters the ventilation system saving energy.

Now the system reverts back to the conventional balanced ventilation system with heat recover as shown in fig 3.

We will try to simulate the system further to test its feasibility for the final presentation. But the concept and aims are outlined above.

5.3 Calculations

About the systems

BEFORE CHANGE:

- ✓ 400mm Polystyrene Foam insulation, U-value 0.1 w/(m2·k)
- ✓ Dimensions (insulation not included):

Six tanks: volume in all-220m3;

Surface area in all-412m2

Assuming the water comes in with temp. Of 90 °C, environment temp. is 18°C.

Q=λ*ΔT*A

λ= 0.1 w/(m2·k); ΔT=temp. inside-temp. Outside; A=412m2.

Results:

The monthly temperature variation is as the following:

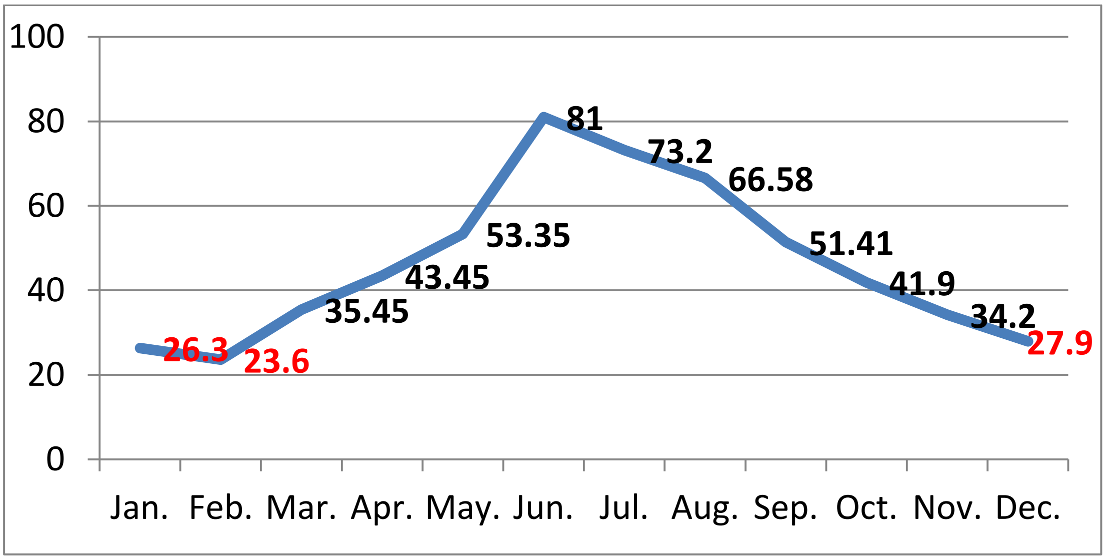


Fig 5. monthly temperature variation (before changes)

If we are using floor heating as the heat strategy, only solar can not cover it during January, February and December. When DHW is included, solar system can not meet the demand in 7 months.

And the lack of Assignment 2 is this calculation did not take heat loss from the tanks, which contributes to space heating, into consideration.

Which leads to the following changes to the system, and also different figures.

AFTER CHANGE:

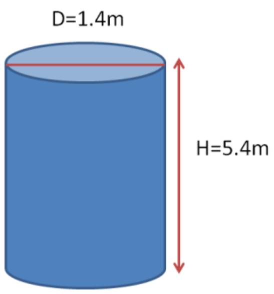
Tank information:

✓ 400mm Polystyrene Foam insulation, U-value 0.1 w/(m2·k)

✓ Dimensions (insulation not included):

Six tanks: volume in all-50m3;

Surface area in all-223.9m2



Assuming the water comes in with temp. Of 80 ℃, environment temp. is 18℃.

Q=λ*ΔT*A

λ= 0.1 w/(m2·k); ΔT=temp. inside-temp. Outside; A=223.9m2.

Results:

And then we got the monthly temperature variation:

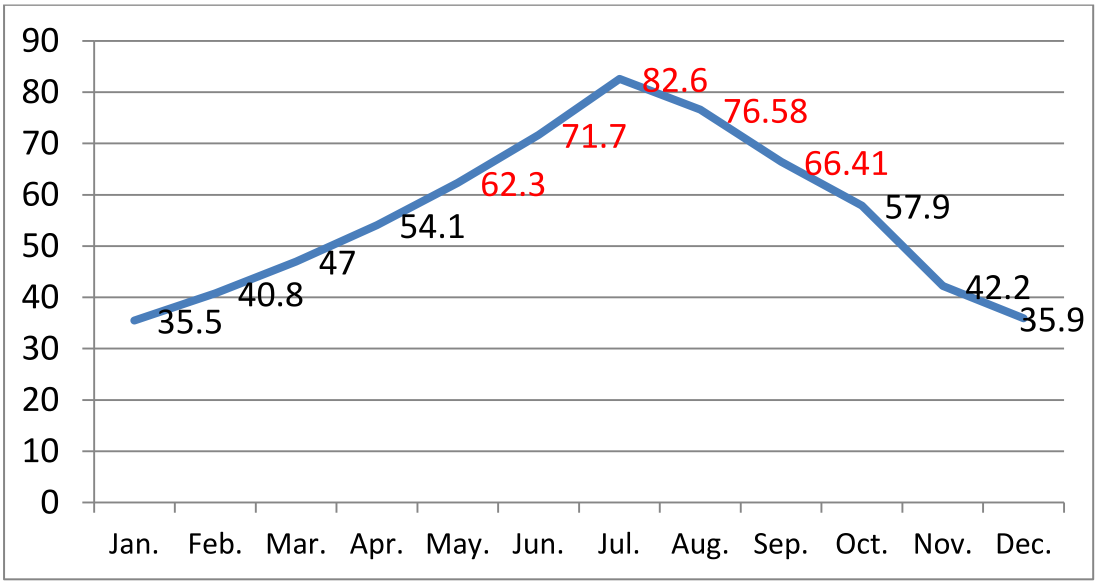


Fig 6. monthly temperature variation (after changes)

5.4 Energy Strategy Proposals

- Minimize heat loss – Envelope(insulation); airtightness, orientation, windows and openings and etc.

- Maximize heat – Solar collectors;
- Passive strategy – Natural Ventilation; heat recovery at the top; thermal mass
- Heat Storage (Active Water Heat Storage System)
- District heating (as a backup solution)

6 PHPP Calculations

U-values of the envelop:

Assembly No.	Building Assembly Description
1	Exterior wall

Heat Transfer Resistance [m²K/W]: interior R_{si}: 0.13; exterior R_{se}: 0.04

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Interior plaster	0.350					15
2.	Calcium Silicate Bloc	1.100					90
3.	Polystyrene Foam	0.034					300
4.	Exterior Render	0.800					15
5.							
6.							
7.							
8.							

Percentage of Sec. 2: — Percentage of Sec. 3: — Total: 42.0 cm

U-Value: 0.109 W/(m²K)

Assembly No.	Building Assembly Description
2	Roof

Heat Transfer Resistance [m²K/W]: interior R_{si}: 0.10; exterior R_{se}: 0.04

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Chipboard	0.130					50
2.	Blown Mineral Wool	0.040					300
3.	Gypsum Plasterboard	0.700					13
4.							
5.							
6.							
7.							
8.							

Percentage of Sec. 2: 2.0% Percentage of Sec. 3: — Total: 36.3 cm

U-Value: 0.124 W/(m²K)

3	Ground Floor					
Assembly No.	Building Assembly Description					

Heat Transfer Resistance [m²K/W] interior R_{si} : 0.17

exterior Rse: 0.17

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Parquet	0.130					10
2.	Screed	1.050					48
3.	Impact sound insulati	0.040					25
4.	Concrete	2.100					190
5.	Polystyrene Foam	0.040					90
6.	Plaster Coat	0.800					10
7.	Concrete	2.100					100
8.							

Percentage of Sec. 2 | Percentage of Sec. 3 | Total 47.3 cm

U-Value: 0.287 W/(m²K)

4	Partition wall					
Assembly No.	Building Assembly Description					

Heat Transfer Resistance [m²K/W] interior R_{si} : 0.13

exterior R_{se} : 0.13

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Interior Plaster	0.350					15
2.	Calcium Silicate Bloc	1.100					175
3.	Insulation	0.040					80
4.	Calcium Silicate Bloc	1.100					175
5.	Interior plaster	0.350					15
6.							
7.							
8.							

Percentage of Sec. 2 | Percentage of Sec. 3 | Total 46.0 cm

U-Value: 0.375 W/(m²K)

windows:

G-value: 0.5

U-value: 0.8

Ventilation Data:

1. Air change rate=0.6 *1/h*

			for Annual Demand:	for Heat Load:		
Wind Protection Coefficient, e			0.07	0.18		
Wind Protection Coefficient, f			15	15	Net Air Volume for Press. Test	V_{n50}
Air Change Rate at Press. Test	n_{50}	1/h	0.60	0.60	7136	m³

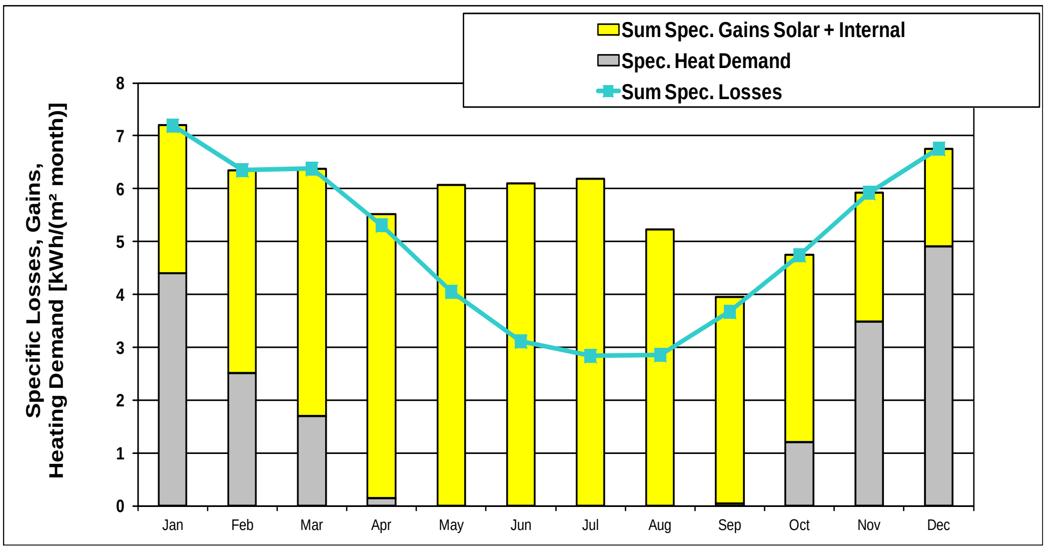
Type of Ventilation System

				for Annual Demand:	for Heat Load:
x	Balanced PH Ventilation	*Please Check*			
	Pure Extract Air				
	Excess Extract Air		1/h	0.00	0.00
	Infiltration Air Change Rate	$n_{V,Res}$	1/h	0.048	0.119

Specific Demands with Reference to the Treated Floor Area

Treated Floor Area:	2523.0	m^2
	Applied:	Monthly Method
Specific Space Heat Demand:	**18**	**$kWh/(m^2a)$**
Pressurization Test Result:	**0.6**	**h^{-1}**
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	**48**	**$kWh/(m^2a)$**
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	**26**	**$kWh/(m^2a)$**
Specific Primary Energy Demand Energy Conservation by Solar Electricity:		**$kWh/(m^2a)$**
Heating Load:		**W/m^2**
Frequency of Overheating:	**29**	**%**
Specific Useful Cooling Energy Demand:		**$kWh/(m^2a)$**
Cooling Load:		**W/m^2**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - E	17.9	15.8	15.7	13.0	9.7	7.3	6.6	6.7	8.8	11.6	14.6	16.8	144	kKh
Heating Degree Hours - G	6.6	6.1	6.7	6.3	6.3	5.8	5.8	5.7	5.6	5.9	6.0	6.4	73	kKh
Losses - Exterior	17229	15174	15152	12515	9350	7039	6342	6414	8494	11141	14109	16155	139113	kWh
Losses - Ground	924	847	932	880	875	812	810	797	777	826	832	896	10208	kWh
Sum Spec. Losses	7.2	6.3	6.4	5.3	4.1	3.1	2.8	2.9	3.7	4.7	5.9	6.8	59.2	kWh/m²
Solar Gains - North	84	252	546	819	1281	1617	1449	861	420	210	105	42	7687	kWh
Solar Gains - East	130	377	695	1013	1354	1543	1507	1107	589	353	118	35	8820	kWh
Solar Gains - South	2552	4671	5248	5826	6067	5634	5971	5248	3948	3708	1830	578	51281	kWh
Solar Gains - West	149	433	826	1287	1666	1693	1679	1246	623	393	135	41	10172	kWh
Solar Gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Gains - Opaque	180	376	557	780	1011	1087	1068	783	455	324	142	46	6808	kWh
Internal Heat Gains	3942	3560	3942	3815	3942	3815	3942	3942	3815	3942	3815	3942	46413	kWh
Sum Spec. Gains Solar +	2.8	3.8	4.7	5.4	6.1	6.1	6.2	5.2	3.9	3.5	2.4	1.9	52.0	kWh/m²
Utilisation Factor	100%	100%	100%	96%	67%	51%	46%	55%	93%	100%	100%	100%	78%	
Annual Heat Demand	11117	6351	4270	363	0	0	0	0	103	3038	8796	12367	46406	kWh
Spec. Heat Demand	**4.4**	**2.5**	**1.7**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.2**	**3.5**	**4.9**	**18.4**	kWh/m²

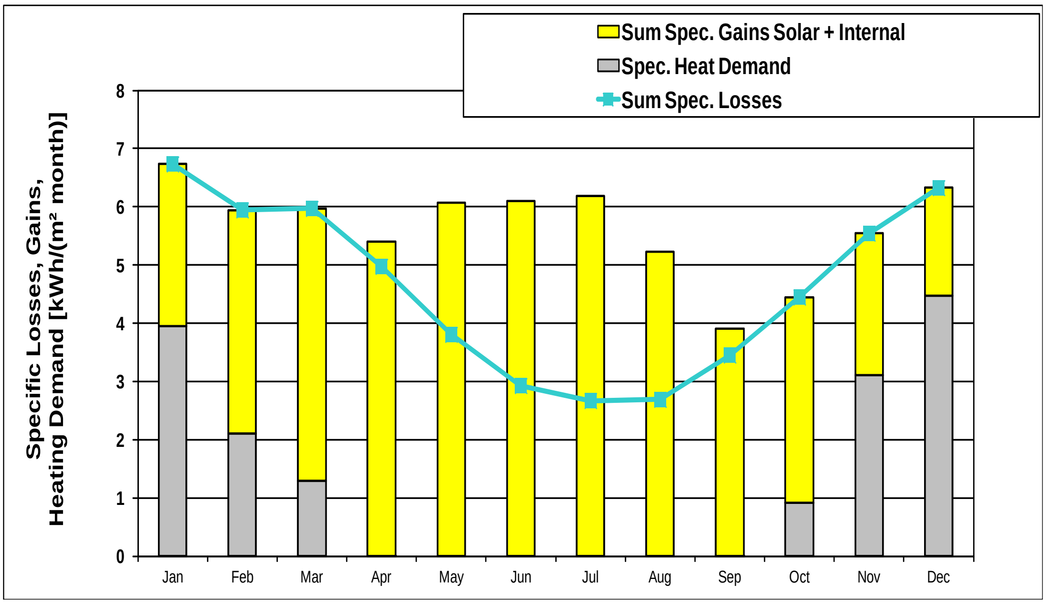


2. Air change rate=0.2 *1/h*

Wind Protection Coefficient, e			0.07	0.18		
Wind Protection Coefficient, f			15	15	Net Air Volume for Press. Test	V_{n50}
Air Change Rate at Press. Test	n_{50}	1/h	0.20	0.20	7136	m³

Specific Demands with Reference to the Treated Floor Area		
Treated Floor Area:	2523.0	m²
	Applied:	**Monthly Method**
Specific Space Heat Demand:	**16**	**kWh/(m²a)**
Pressurization Test Result:	**0.2**	**h^{-1}**
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	**46**	**kWh/(m²a)**
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	**24**	**kWh/(m²a)**
Specific Primary Energy Demand Energy Conservation by Solar Electricity:		**kWh/(m²a)**
Heating Load:		**W/m²**
Frequency of Overheating:	**29**	**%**
Specific Useful Cooling Energy Demand:		**kWh/(m²a)**
Cooling Load:		**W/m²**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	
Heating Degree Hours - E	17.9	15.8	15.8	13.0	9.7	7.3	6.6	6.7	8.8	11.6	14.7	16.8	145	kKh
Heating Degree Hours - G	6.6	6.1	6.7	6.3	6.3	5.8	5.8	5.7	5.6	5.9	6.0	6.4	73	kKh
Losses - Exterior	16066	14150	14132	11674	8727	6573	5925	5992	7929	10395	13159	15066	129790	kWh
Losses - Ground	924	847	932	880	875	812	810	797	777	826	832	896	10208	kWh
Sum Spec. Losses	6.7	5.9	6.0	5.0	3.8	2.9	2.7	2.7	3.5	4.4	5.5	6.3	55.5	kWh/m²
Solar Gains - North	84	252	546	819	1281	1617	1449	861	420	210	105	42	7687	kWh
Solar Gains - East	130	377	695	1013	1354	1543	1507	1107	589	353	118	35	8820	kWh
Solar Gains - South	2552	4671	5248	5826	6067	5634	5971	5248	3948	3708	1830	578	51281	kWh
Solar Gains - West	149	433	826	1287	1666	1693	1679	1246	623	393	135	41	10172	kWh
Solar Gains - Horiz.	0	0	0	0	0	0	0	0	0	0	0	0	0	kWh
Solar Gains - Opaque	180	376	557	780	1011	1087	1068	783	455	324	142	46	6808	kWh
Internal Heat Gains	3942	3560	3942	3815	3942	3815	3942	3942	3815	3942	3815	3942	46413	kWh
Sum Spec. Gains Solar +	2.8	3.8	4.7	5.4	6.1	6.1	6.2	5.2	3.9	3.5	2.4	1.9	52.0	kWh/m²
Utilisation Factor	100%	100%	100%	92%	63%	48%	43%	51%	88%	100%	100%	100%	76%	
Annual Heat Demand	9955	5328	3251	88	0	0	0	0	20	2293	7847	11278	40059	kWh
Spec. Heat Demand	**3.9**	**2.1**	**1.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**3.1**	**4.5**	**15.9**	kWh/m²



7 Conclusion

Equipment choosing:

First of all, if we use floor heating system, temperature over 30 degrees can be used for heating. Which means if we only have solar collectors as heat gain method, the temperature is sufficient. But the quantity of water is too small(50M3). Therefore, we have to increase temperature, in order to decrease quantity to get to the same amount of energy. So, radiators will be the ultimate solution.

DHW:

According to the DHW requirements, temperature over 60 degrees is usable. The diagram shows in summer, only solar collectors are sufficient for DHW, from May to September. And on other months, wood and pellets boiler will be added to the system to get more energy input.