Many approaches of sustainable architecture in cold climates are geared only towards energy-savings, disregarding non-quantifiable aspects of architectural relevance such as spatial quality and aesthetics. These approaches often create a feeling of imprisonment rather than inhabitation. In contrast to these approaches we propose an architectural concept based on the tension between open and closed spaces, between private rooms and the direct contact with the nature.

The building spaces are placed over a slab of recycled concrete. The entire building is covered by a semi-transparent photovoltaic glass roof that offers spectacular sights into the sky and extraordinary daylight qualities. Walls and beams of recycled cardboard, arranged in a structural grid, partition the space and provide a durable envelope to the exterior climate and strength against the wind and the snow.

The interior spaces achieve a high spatial diversity ranging from closed intimate rooms to public and open spaces. The rooms are defined by transient boundaries in which mobile elements allow to adjust visual and physical transparencies. The boundaries of the house are also the interface of the energetic interactions between the inner and the outer space. The interactions occur in the form of passive solar heat gains that reduce the heating demand, natural ventilation that reduces the cooling demand, and the harvesting of solar energy in form of electricity and heat.

The boundaries of the building further expand deep into the ground to exploit the constant temperature of the soil as heat source for an efficient heat pump operation in the winter and as a direct cold source in the summer. The ground is also used as seasonal heat storage to make available in the cold winter the abundant thermal energy harvested by the thermal collectors during the summer. The combination allows an energetic operation without any transitional storage. The produced heat and electricity needs to be stored because the dynamics of the building demand and of the roof supply are not matching. The heat is stored in the ground and electricity is stored in the public electrical network.

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Energy simulations:

The building features a highly sustainable materiality with very low grey emissions by using recycled materials for the slab and the walls. Cardboard is made of wood fibres, a renewable resource, and is the most recycled material of the world.

The building also features a highly sustainable energy balance, with the energy production being equal or larger than the energy demand, using local, renewable energy-sources. The positive energy balance is also exploited to allow slightly higher heat losses through the glazed roof to keep it free of snow in wintertime. In this way, high-quality daylighting, solar heat gains, and electricity generation are maintained even during the snow season.

Technical systems:

Winter mode
On the source side of the heat pump the water is first heated in the ground and successively in the photovoltaic-thermal collector if solar heat is available. On the sink side the heat pump supplies the floor heating system or the domestic hot water.

Summer mode
The heat of the photovoltaic-thermal collector is used to regenerate the ground heat in the hot season. Alternatively the ground is used as direct cold source in the summer.

Electricity
The photovoltaic roof is connected to the internal appliances and to the public electrical network.

Cost estimation: 200'000 USD based on projects realised in Switzerland.

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heat pump

ground heat 12°C

borehole 100m

semi-transparent photovoltaic-glass roof, the sleeping room is covered by opaque photovoltaic-thermal collectors

solar heat gains to reduce the heating demand

sliding of the snow due to low-friction material (glass)

and melted patina due to internal heat

water-based floor heating system supplied by a ground-source heat-pump (ground to store and recover heat)

walls of recycled cardboard (low cost)

humidity and radiation resistant cardboard

recycled concrete slab (thermal mass, elevation from ground)

closed situation

intimate spaces, private rooms and inner garden, views into nature

open situation

blurry spaces, public, physical transparency, open garden, views into nature

winter

solar heat gains and floor heating system to heat the interior

summer

natural ventilation to reduce cooling demand and floor-ground coupling to provide cooling

Zero emission local energy sources