SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA SHC Solar Academy Webinar, *September 19th and 21st 2023*

Concepts for new and existing Solar Energy Buildings and building blocks

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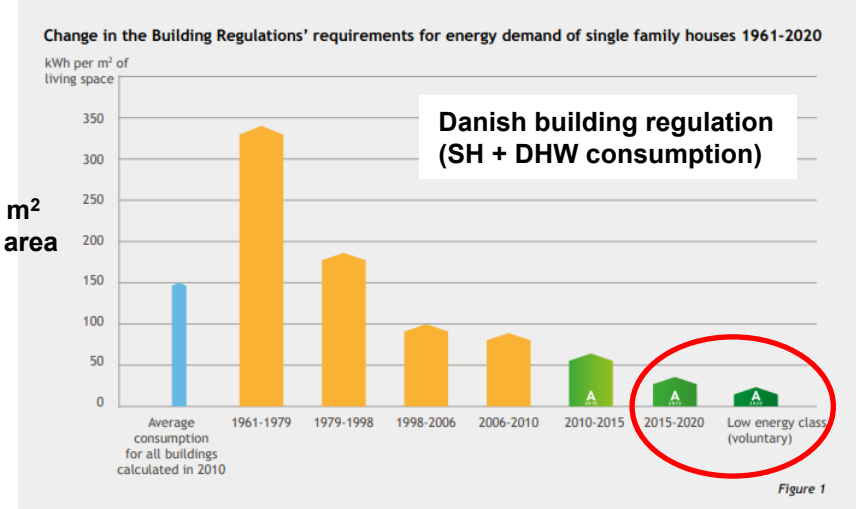
eUDP

DTU

Agenda

- What is important to reach a high degree of self-sufficiency?
- Solar Energy Buildings around the world - Demonstration cases
- Trends

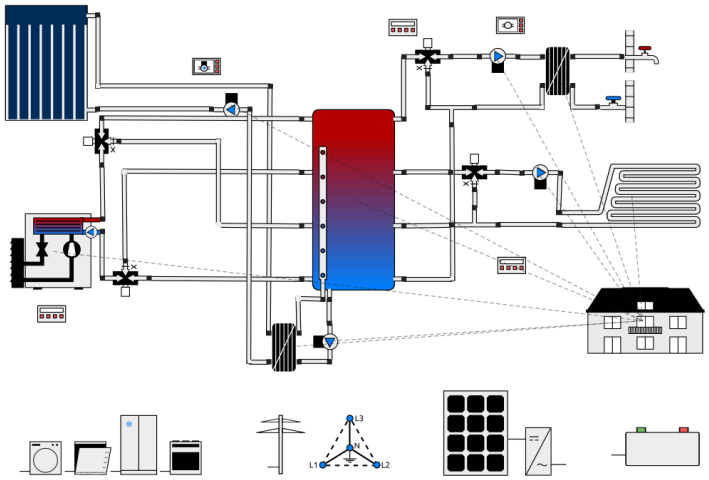
What is important to reach a high degree of self-sufficiency?



kWh per m² of living area

Type of household	SH, ventilation, cooling, and DHW demand (kWh/year)	Electricity demand (kWh/year)	Total energy demand (kWh/year)	Reduction (%)
BR18 mandatory	4600	2700	**7300**	**0**
BR18 voluntary – Building class 2020	2400	2700	**5100**	**30**

POLYSUN model



Self-sufficiency

$$\frac{Total\ energy\ demand - Electricity\ bought\ from\ the\ electric\ grid}{Total\ energy\ demand}$$

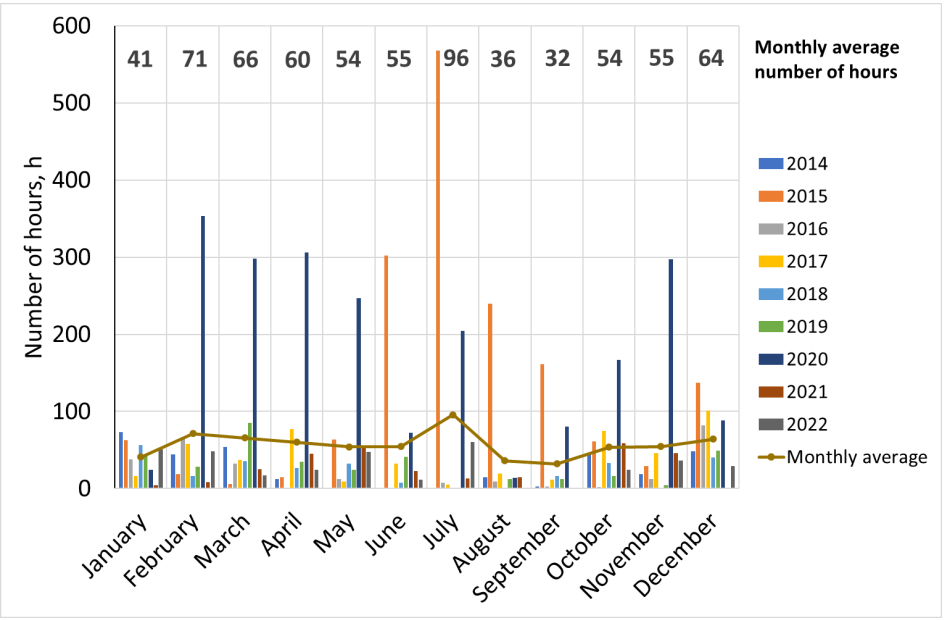
Reference conditions

- Two single-family house of 120 m² with two residents
- Solar thermal, PV, HP, Combi tank with two temperature levels, Battery, two-axis tracking for solar thermal collector and PV panel
- Danish climate: Temperate (55.7° N, 12.6° E)

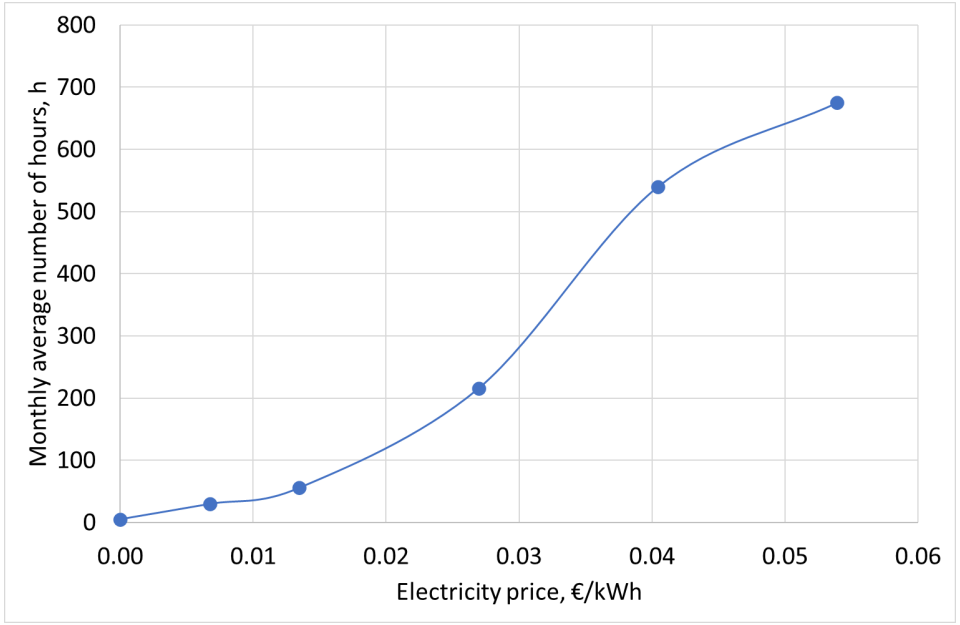
Results (Self-sufficiency of **90%** for both houses)

- BR18 mandatory: **54** m² solar thermal collectors, **3** kW HP, **48** m² PV panels. **21.4** m³ thermal storage and **30** kWh battery storage.
- BR18 voluntary: **33** m² solar thermal collectors, **2.2** kW HP, **48** m² PV panels, **12** m³ thermal storage, and **30** kWh battery storage
- **30% less energy demand** leads to a reduction of **39%** solar thermal collector area, **36%** HP power, and **44%** thermal energy storage capacity

Number of hours with low electricity spot-prices in Denmark



Number of hours with spot prices lower than 0.0135 €/kWh



Number of hours with different spot prices in €/kWh

Electricity spot prices from Nord Pool (nordpoolgroup.com)

This is important to reach a high degree of self-sufficiency at a low cost

- Reduce the energy demand for buildings
- Use low-temperature heating systems (floor heating or oversized radiator)
- Use solar energy systems to cover the energy demand
- Reduce electricity consumption when renewable electricity is limited – use energy storage
- Use smart control systems to improve the interplay with the energy grids and further reduce the system size and costs

Demonstration cases (20)

Former industrial complex, **Austria**
Commercial/Residential

Innsbruck, **Austria**
Smart city quarter

Tirol, **Austria**
Residential complex

Reference building, **Austria**
Multi-family solar house

Freiburg, **Germany**
Single-family homes

Konstanz, **Germany**
Multi-family houses

Reidberg, **Germany**
Multi-family houses

Cottbus, **Germany**
Multi-family house

Neissestrasse Ludwigsburg, **Germany**
New building district

Weinstadt, **Germany**
New residential building

LNEG campus, **Portugal**
Test champers

Warsaw, **Poland**
Orphanage

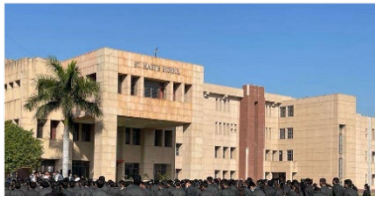
Aarhus, **Denmark**
Multi-family homes and office

East Beisanhuan Road, **China**
Office building in Beijing

Giggs Place Hilton, **Australia**
Single-family home

Kochi, **India**
College of Social Science

Kochi, **India**
Autonomous Institution



Haryana, **India**
Educational Institution

Delhi, **India**
Hospital

Leh, Ladakh, Himalaya, **India**
Guest house

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Location of demonstration sites

Demonstration Cases Technologies

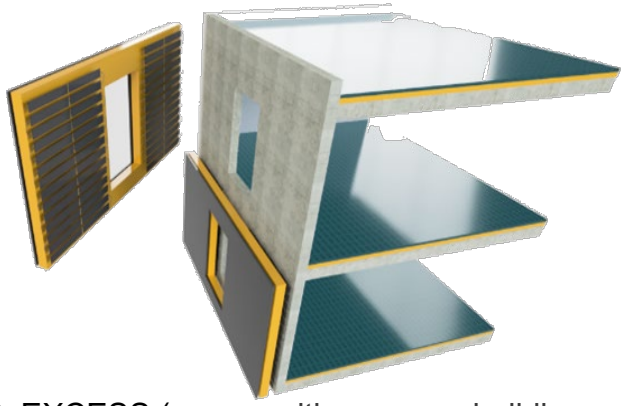
	Country	District heating network	Measurements	Calculations	Number of technologies used	SEB Technologies: Energy source: sun: Photovoltaic	sun: Solar thermal collectors	sun: Solar-air collector	wind: PVT-collectors	wind: Wind turbines	water: Hydropower plant	water: Groundwater and heat pumps	earth: Geothermal and heat pumps	air: Air-source heat pumps	bioenergy: Biomass combustion	bioenergy: Biogas plants	Energy storage: electrical storage: batteries	electrical storage: Mobile batteries (E-mobility)	thermal storage: Hot water storage	thermal storage: Thermochemical storage	thermal storage: Ice storage	thermal storage: Sorption storage	thermal storage: Thermal mass activation
Europe	Austria			X	7	X					X	X					X	X	X				X
	Austria	X		X	7	X			X				X				X	X	X				X
	Austria	X			5	X						X		X					X				X
	Austria	X		X	4	X						X					X		X				
	Germany		X	X	5	X	X										X	X	X				
	Germany		X	X	4	X							X				X		X				
	Germany		X	X	7	X		X					X				X	X	X		X		
	Germany		X		5	X	X										X	X	X				
	Germany	X		X	5				X									X	X		X		X
	Germany	X	X		4	X	X												X		X		
	Portugal				2		X												X				
	Poland				4		X						X						X	X			
	Denmark	X	X	X	6	X			X			X					X	X	X				
Asia	China	X	X	X	3	X											X	X					
	India				1	X																	
	India				2	X	X																
	India				2	X											X						
	India				3	X	X												X				
	Himalaya		X	X	3	X		X															X
	Australia		X		5	X	X							X			X	X						
						17	8	2	3	0	1	4	4	2	0	0	11	9	14	1	3	0	5

Commercial/Residential, Former Industrial Complex, Graz, Austria (47.05° N, 15.43° E)

Climate zone: **Continental**
Significant annual variation in temperature, °with warm summers and cold winters

Buildings
- 31000 m^2
- 15660 m^2 energy renovated to low-energy building standard
- The rest of the complex should meet the passive house standard

Energy system
- Gas boiler of 400 kW (to be replaced by renewable energy system)
- Ground water wells available
- Ground water heat pumps (two), total capacity 165 kW
- PV, 202 kWp installed (Extension to 365 kWp PV planned)
- Hydropower plant, 140 kWp, will be built in the Mühlgang (bypass of the river Mur)
- Battery capacity of 225 kWh planned
- Electric vehicle charging station
- Thermal mass activation



H2020, EXCESS (www.positive-energy-buildings.eu)

Calculated data for the whole area (transformed)
- Heating consumption: 874,200 kWh (28,2 kWh/m^2a)
- Electricity consumption: 914,500 kWh (29,5 kWh/m^2a)
- PV system production: 257,325 kWh (705 kWh/kWp)
- Hydro power: 1193 MWh/a
- Degree of self-sufficiency: **75%**

The energy flexibility potential will be maximized by the use of **thermal activation of massive reinforced concrete façade components, decentralized water storage, and integration of flexibility potential on the side of users (human-centric approach)**

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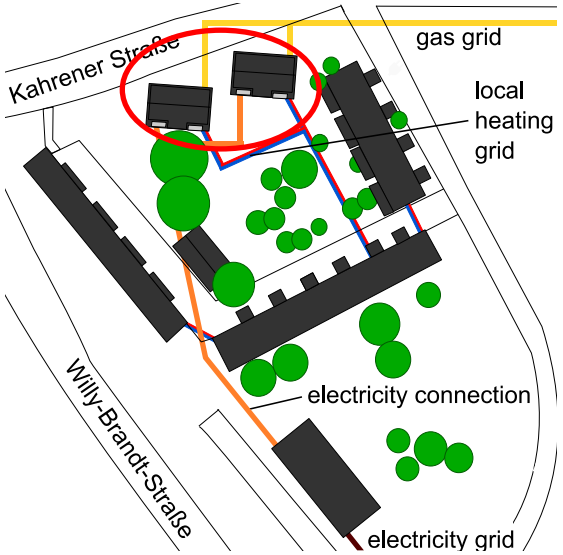
Contact person: **Thomas Ramschak**, t.Ramschak@aee.at

Climate zone: **Continental**
Significant annual variation in temperature, with warm summers and cold winters

Multifamily solar house, Kahrener Straße, Cottbus, Germany (51.76° N, 14.35° E)



Building
- New building from 2019
- Living area: 605 m^2

Energy system
- Solar thermal collector: 100 m^2
- Heat storage: 24.6 m^3
- Gas boiler: 48,2 kW for backup heating (condensing gas boiler)
- PV: 29.6 kWp
- Battery: 46.8 kWh
- Geothermal collector system for cooling
- Electrical vehicle charging station

Surplus of heat and electricity are to be consumed decentrally through **networking and sector coupling in the neighborhood and through e-mobility**.

Performance data (measured)
- Heating consumption: 85 kWh/m^2a
- Electricity: 29.5-32.1 kWh/m^2a
- PV production: 938 kWh/kWp
- Solar thermal energy production: 533 kWh/m^2a
- Degree of self-sufficiency: **93%** (electricity), **83%** (thermal)

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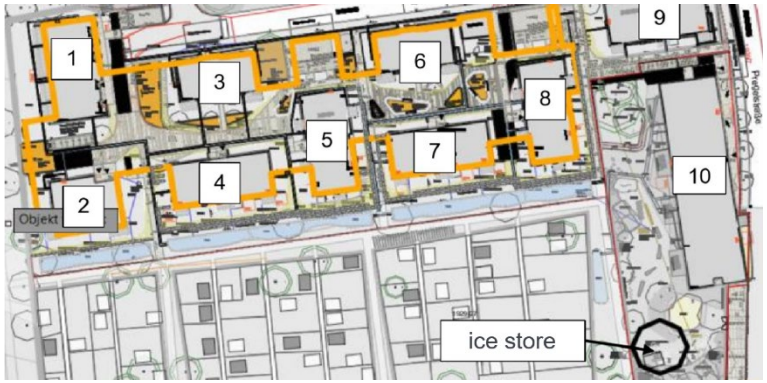
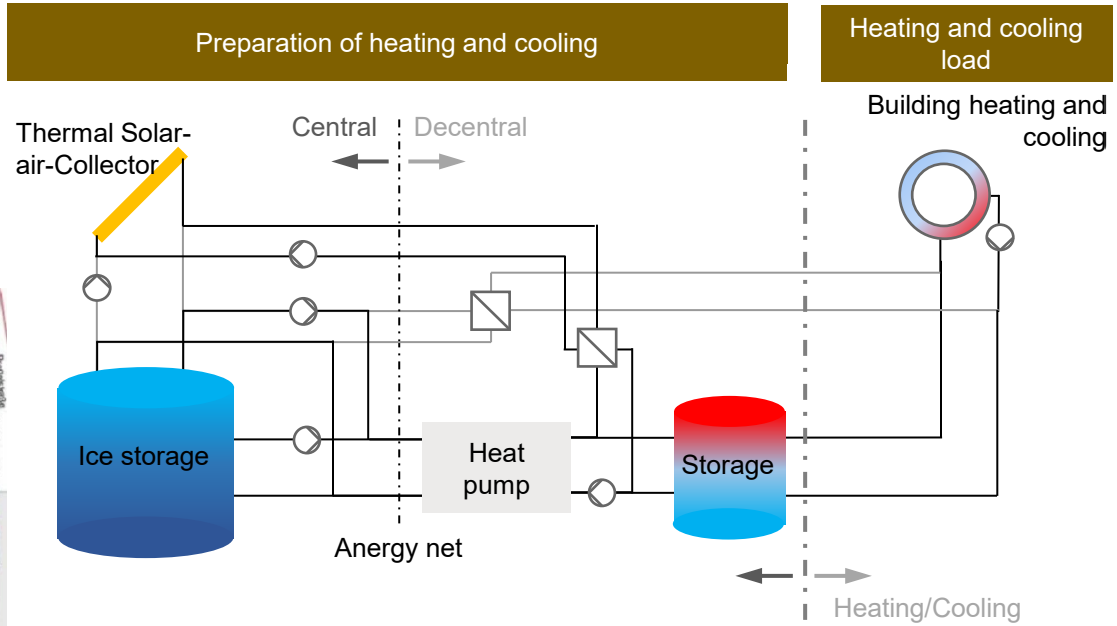
Contact person: **Lukas Oppelt**, lukas.oppelt@tu-freiberg.de

Climate zone: **Continental**
Significant annual variation in temperature, with warm summers and cold winters

Neissestrasse, Ludwigsburg, Germany
New building district (48.88° N, 9.21° E)





Performance data (calculated)
- Heating: 508000 kWh/a
- Cooling: 167000 kWh/a
- Electricity: 363203 kWh/a
- Degree of self-sufficiency: **53%**
  (H: **78.6%**, C: **33.1%**, E: **28.2%**)

Buildings
- New building district from 2022
- 8567 m^2 – 9 multi-family buildings + 1 building with kindergarten with three residential units above

Energy systems
- Floor heating/cooling system
- HP, Brine-water, 29-42,8 kW
- Thermal storage
- DHW: electric instantaneous water heaters at each tapping location
- Ice storage 660 m^3
- Solar air collector, 137 m^2
- PV panels, 220 kWp (1085 m^2)

Contact person: **Stefanie Lott**, stefanie.lott@igte.uni-stuttgart.de

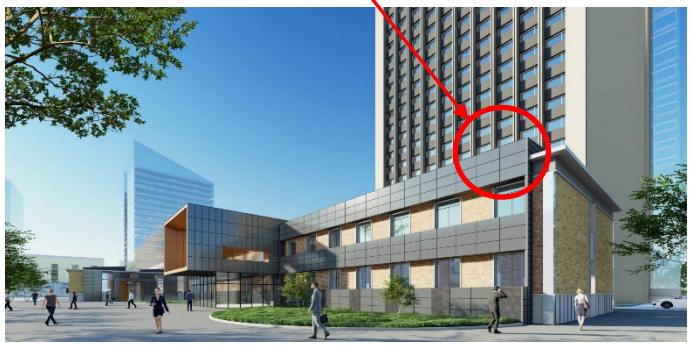
East Beisanhuan Road, China. *Office building in Beijing, CABR (net ZEB)* (39.96° N, 116.41° E)

Climate zone: **Continental**
Significant annual variation in temperature with cold sunny winters and hot, sultry, and rainy summers (Monsoon)

Before: 3000 m² office building (1970)

After: 3000 m² energy renovated office building + 235 kWp PV (2021)

PV modules as shadow curtain

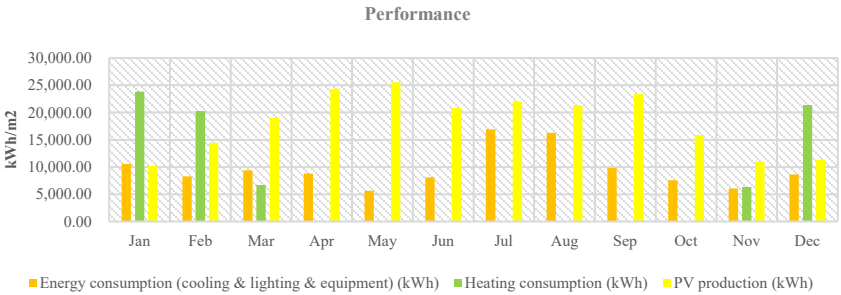


Monocrystalline silicon
569 m² (115 kWp)

Thin film
849 m² (118 kWp)

Transparent thin film
51.6 m² (2.2 kWp)

Energy generation per unit building area kWh/m2	Energy consumption per unit building area kWh/m2	Heating consumption per unit building area kWh/m2	Net energy output per unit building area kWh/m2
+67	-40	-12	+15



Energy systems

- PV panels
- DHW: Electrically heated hot water tank
- Summer: Split air conditioner
- Winter: District heating
- Electric vehicle charging station

Performance data 2022

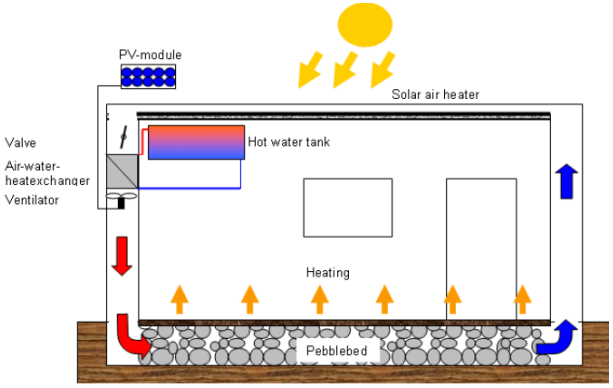
- Heating consumption: 78,485 kWh;
- Electricity consumption: 116,041 kWh
- PV system production: 219,561 kWh
- Degree of self-sufficiency: **31%**

Contact persons: **Xinyu Zhang**, zxyhit@163.com and **Wenbo Cai**, c18519533681@163.com

Kurja Guest house, Leh, Ladakh, Himalaya (India) (34.16° N, 77.58° E)

Climate zone: **Subartic**
Cool summers and dry cold and sunny winters with heating season > 6 months (Mountain, 3500 m)

Schematic of heating system and Kurja Guest house with solar air heater on roof



Traditional homes only heat the living room, where the whole family is assembled around a Bukari oven

Bukari: Wood-burning or charcoal stove

Big thermal mass capacity

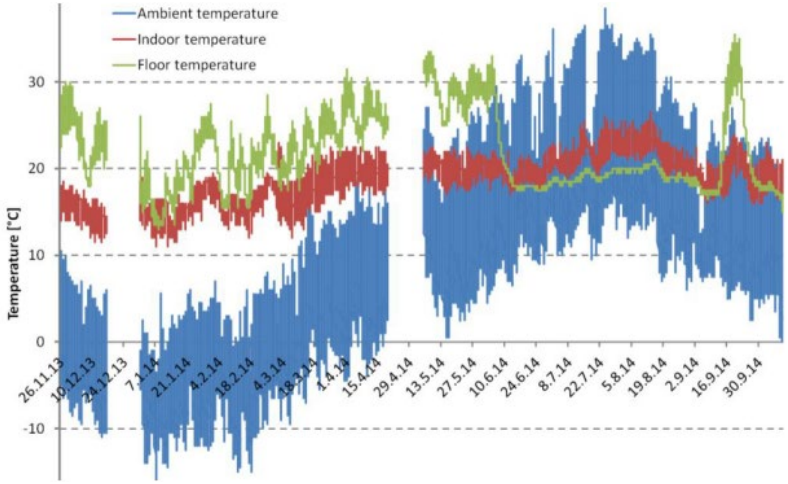
- Ensures room heating 24 hours daily, even during 1-2 days without sun
- No more searching for fire-wood or buying charcoal or gas
- No more smoke in the rooms, which contributes to respiratory diseases or carbon monoxide incidents

Energy systems

- Solar-air collector
- Pebble bed storage
- Thermal mass activation
- PV panels for a ventilator (air circulation)

Performance data (measured)

- Heating consumption: 580 kWh/m^{2}a. Reduced to 380 kWh/m^{2}a after basic heat protection
- Solar air heater production: 1,4 kWh/m^2/day during the heating season
- Degree of self-sufficiency: **94%** (measured)



Measured temperatures 26.11.2013-10.10.2014

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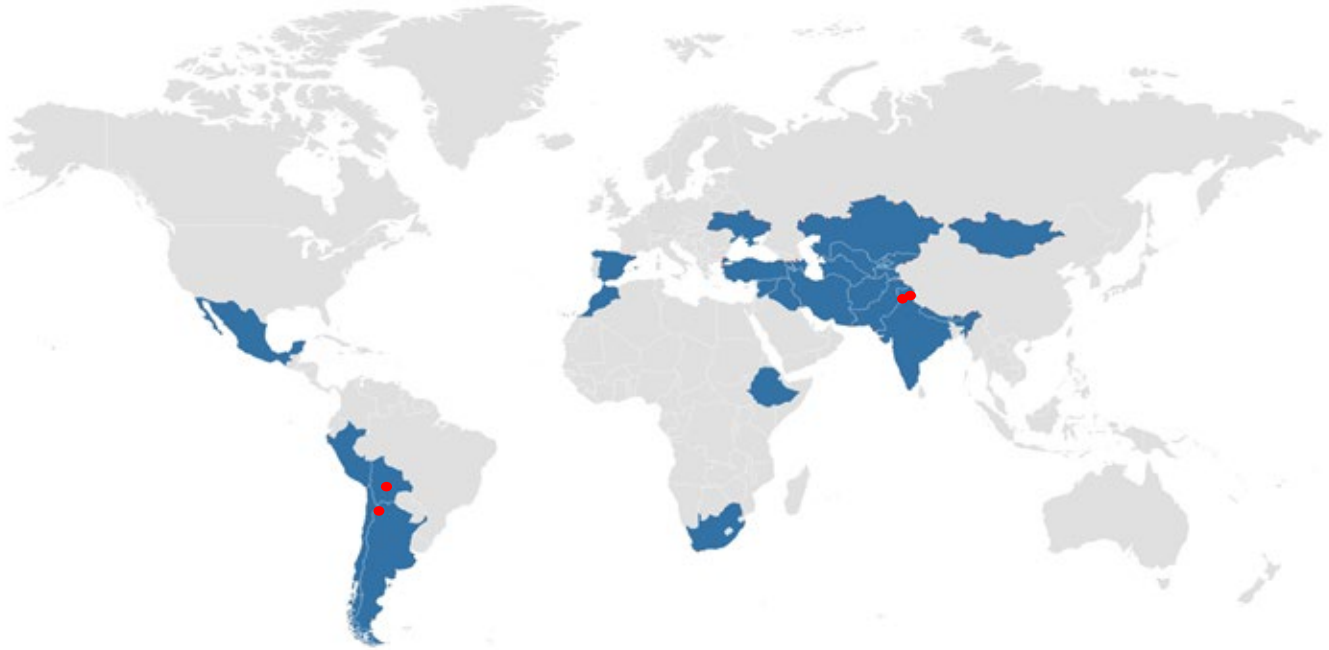
Contact person: **Christoph Müller**, c.mueller@simply-solar.de

Target group

Regions with cold but sunny winters, suitable for the proposed technology are often found in southern countries with high mountain regions (pilot projects marked red):



Potential project areas and existing pilot projects

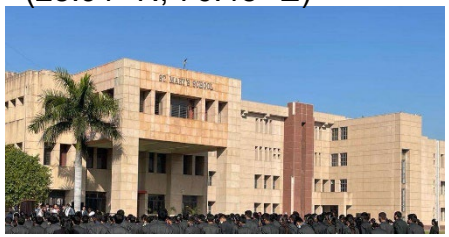
India

Energy demand for cooling and domestic hot water

Holy Family Hospital, Delhi
(28.56° N, 77.27° E)

Energy system
- Grid-connected 300 kWp PV panels
- Split AC for cooling
- DHW electric boiler
- Four solar domestic hot water systems - flat plate and evacuated tube solar collectors
- Diesel generator for electricity backup

St. Mary School, Haryana (School and hostel)
(28.91° N, 76.48° E)



Energy system
- Stand-alone 40 kWp PV panels (unstable electric grid)
- 144 kWh batteries
- Split AC for cooling
- Electric heated DHW
- Diesel generator for electricity backup

Rajagiri Autonomous Institutions, Kochi
(09.99° N, 76.36° E)

Energy system
- Grid-connected 717 kWp PV panels
- Thermo-siphoning solar heating system for DHW
- Split AC for cooling
- Diesel generator for electricity backup

Rajagiri College of Social Science, Kochi
(10.05° N, 76.31° E)

Energy system
- Grid-connected 267 kWp PV panels
- Split AC for cooling
- Diesel generator for electricity backup

Delhi and Haryana

Climate zone: **Subtropical**
Long hot summers (dry summer and humid monsoon) and short and mildly cold winters

Kochi - India

Climate zone: **Tropical**
High temperature all year
Rainy season Apr.-Nov.
Dry season Dec.-Mar.

Contact person: **Arun Kumar V**, akv@steag.in

Climate zone: **Mediterranean,**
Warm Temperate (NCC Zone 5)
Mild winters and hot to very hot summers

Giggs Place Hilton (WA), Australia. Single-family house (-32.07° S, 115.78° E)

Electrical heated and cooled house

Josh's house built in 2013 and renovated in 2018

Energy systems and technologies

- PV panels, 6.4 kWp + 5 kWp inverter (ca. 32 m2)
- Battery storage 10 kWh
- HP, Air-Water
- Electrical vehicle charging station
- Collection and recycling of most of its water
- Integrated water system in conjunction with UV disinfection system, which can collect up to 32000 l of rainwater (meets the internal demand for up to 8 months)
- Uses the Grey Flow Diversion Device to process and collect the greywater generated from laundry and bathroom for irrigation usage
- Landscaping includes food production, wildlife habitat, and play spaces
- Continuous monitoring of the house's energy performance

Performance data 2018

- Electricity consumption: 6041 kWh/a
- PV system production: 10782 kWh/a
- Degree of self-sufficiency: **89%**

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Contact person: Rebecca Yang, rebecca.yang@rmit.edu.au

Trends

Europe

- Systems with a mixture of a high number of different technologies
- PV, HP, Battery, Solar thermal, anergy network, ice storage, advanced control strategies and thermal mass activation

Asia

- Systems with few different technologies
- PV, battery, Solar thermal and thermal mass activation

Thanks for listening!

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