Sustainable Built Environment Conference, 12. September 2019, TU-Graz

Mobile Tiny Homes – Sustainable & Affordable?

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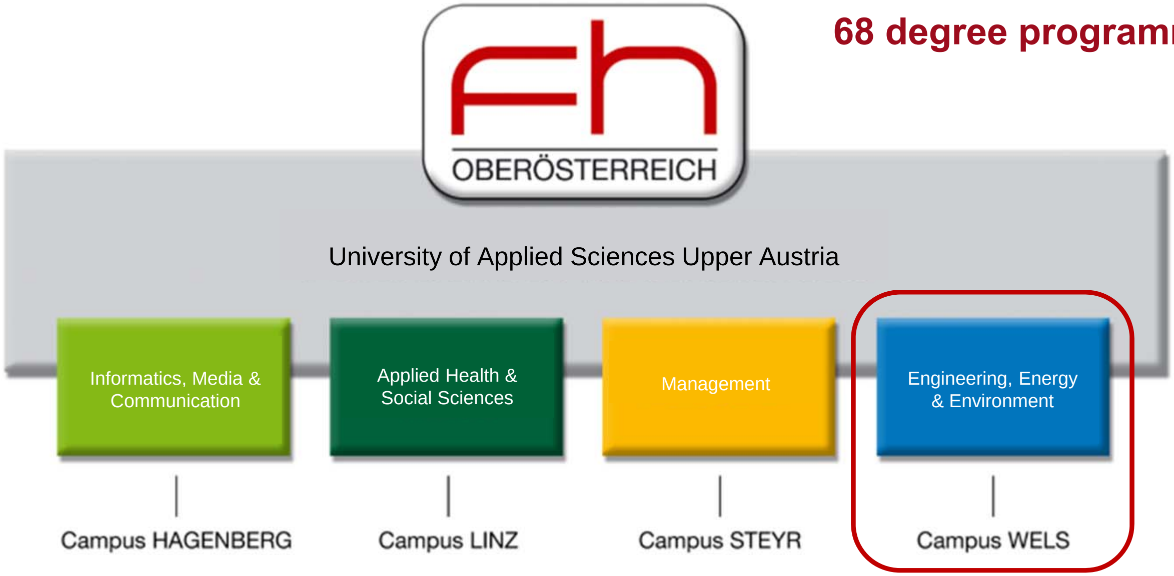
68 degree programmes at 4 campuses



Campus Wels: „Eco-Energy Engineering“ (since 2002) > 2019 “Applied Energy Engineering”

Unique combination of electrical engineering, mechanical engineering, civil engineering, building technologies and renewable energy systems

Content

1. Development of a building technology concept in modular design (master thesis Lukas Krainz)
2. Energy self-sufficient cabin (interdisciplinary project)
3. Practical example (economic efficiency & environmental sustainability

Genböck / Leindecker

Examples for tiny houses:

Wohnwagon

Microloft

Flexbox

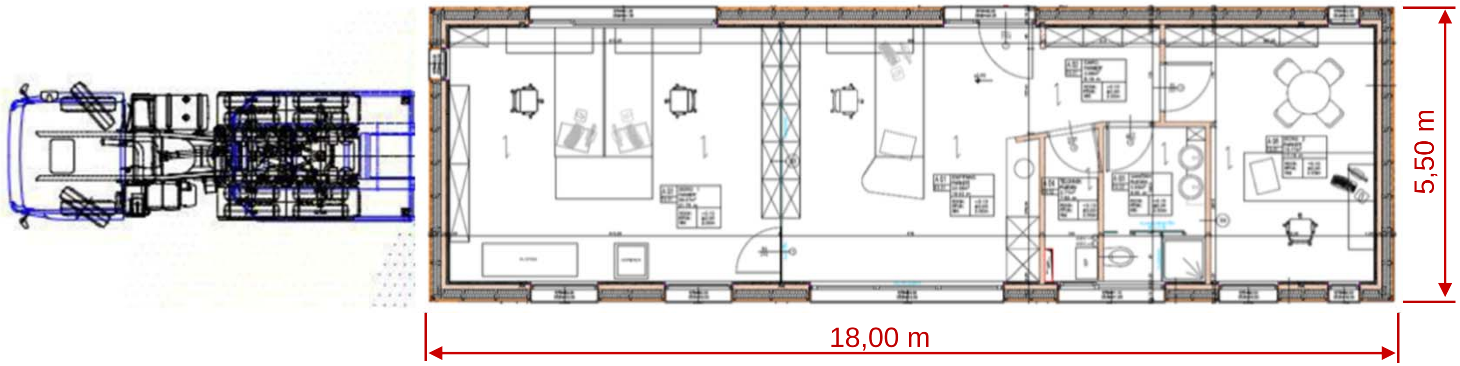
holzheim…

1. Modular Design: Development Building of a Technology Concept (Lukas Krainz)

- Description of the current building technology concept
- Development of an innovative building technology concept with focus on heating system and air ventilation
- Photovoltaic simulation
- klimaaktiv building declaration

Source: Lukas Krainz, Master Thesis 2018

1. Modular Design: Mobility of buildings



Source: Lukas Krainz, Master Thesis 2018

- Example from Master Thesis: Level 4 Special Transport → Three escort vehicles including three road supervisory authorities are required!

- Balancing act between industrial prefabrication and transportability

- Infrastructure sets the dimension (roads, bridges, underpasses,...)

- In Austria, the transport is regulated in the so called “Special Transport Order” (SOTRA).

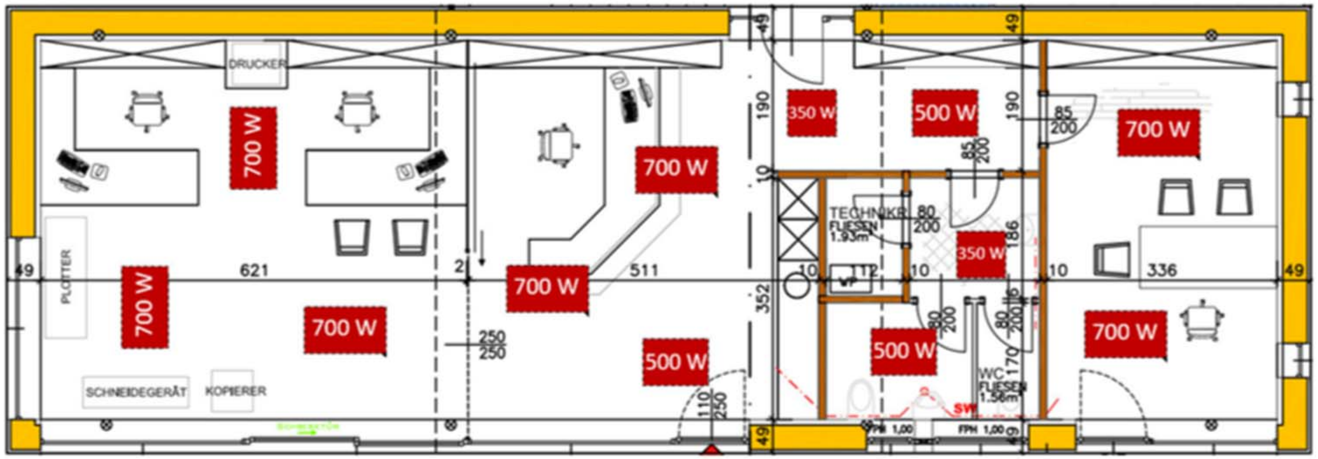
1. Modular Design: Special Transport Levels

	Level 1	Level 2	Level 3	Level 4
Width	3,01 – 3,20m	3,21 – 4,50m	4,51 – 5,00m	from 5,01
Height	-	from 4,31m	-	-
Length	22,01 – 25,00m	25,01 – 40,00m	from 40,01m	-
Weight	individual (depending on weight, axle load and requirements of the expert opinion of the road administration)			from 140,01t
Legal Requirements	self-accompaniment	1 Vehicle incl. 1 sworn road supervisory authority	2 Vehicles incl. 2 sworn road supervisory authorities	min. 3 Vehicles incl. min. 3 sworn road supervisory authorities

Source: SOTRA

1. Modular Design: Infrared Heating System

Ground Floor,
only one level



Source: Lukas Krainz, Master Thesis 2018

1. Modular Design: Infrared Heating System

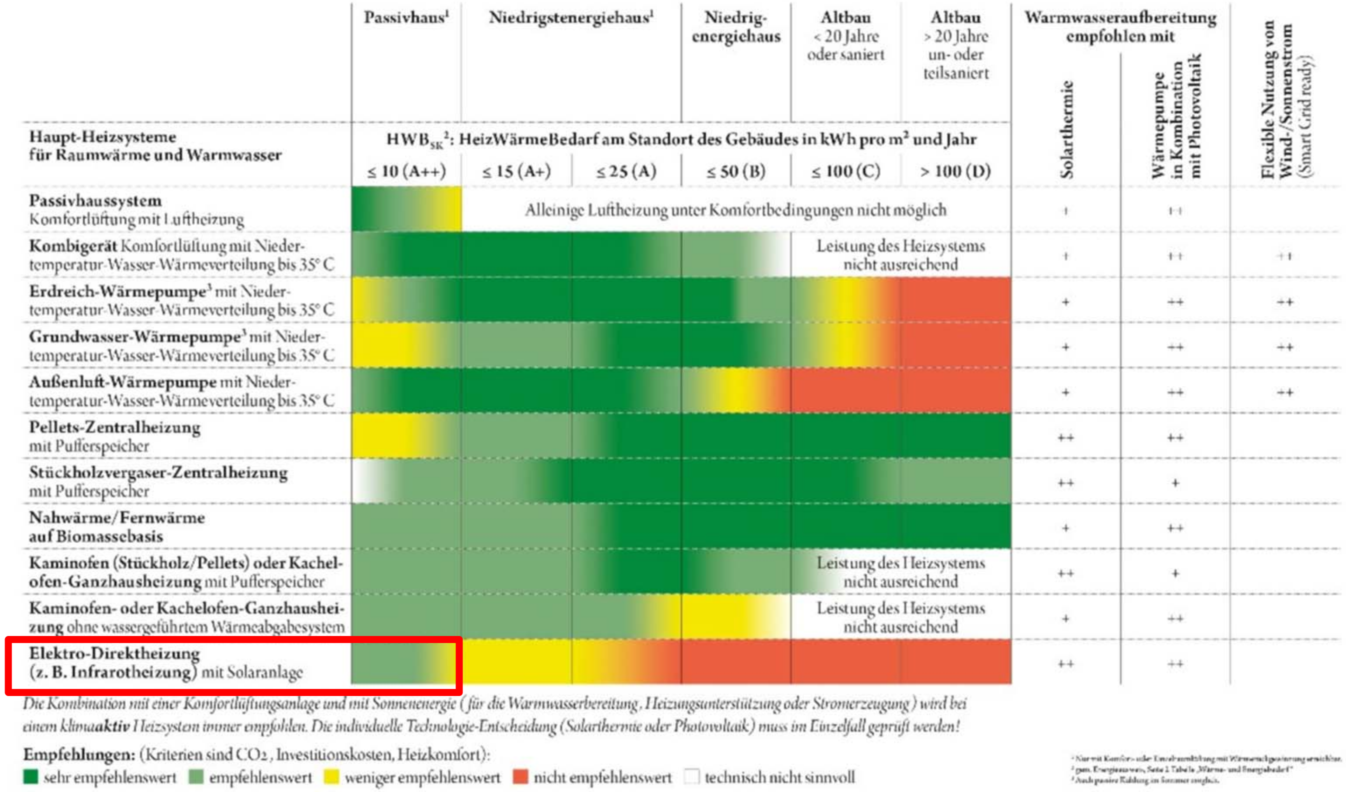
Advantages & Disadvantages

- Low investment & maintenance costs
- Quick heating times & greater flexibility
- High radiation content / low convection content

- High-quality form of energy for heating
- Additional system for hot water generation is needed
- High electricity price → high operating costs
- Only for nearly-zero energy buildings (HWB $\leq$ 10 kWh/m^2a)

1. Modular Design: Infrared Heating System

Conclusion An infrared heating system can only be operated economically if:

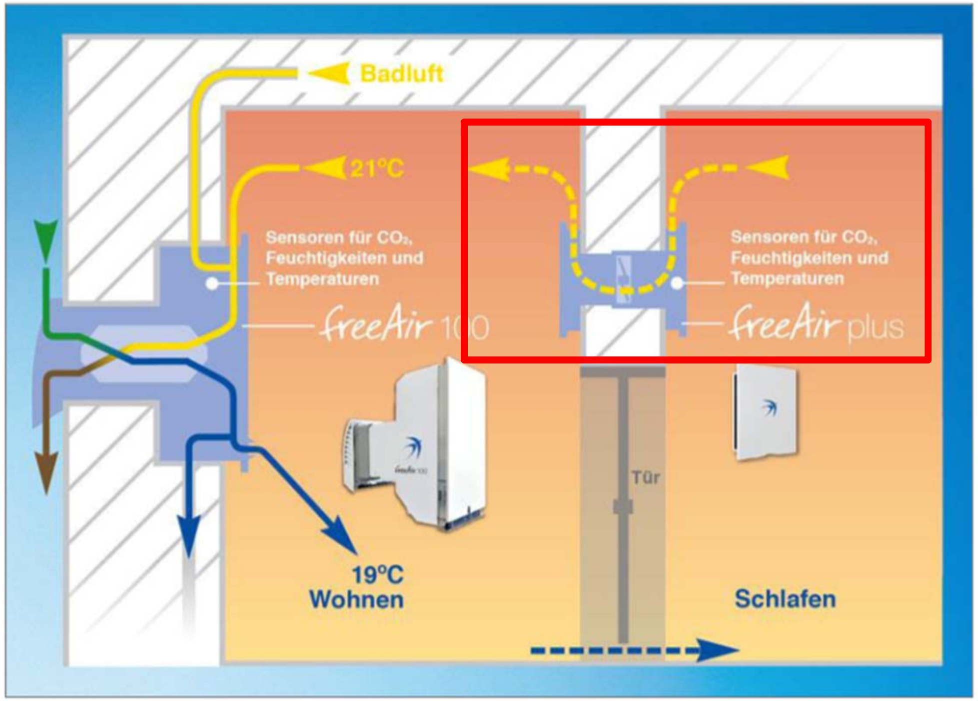


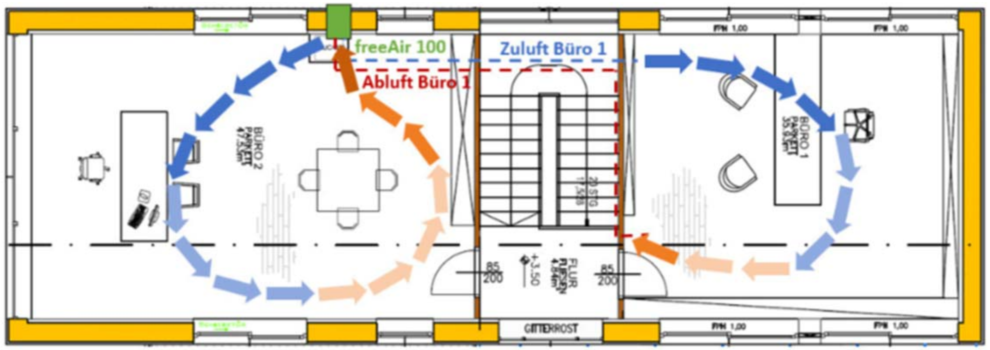
- Very good thermal building envelope conditions → **HWB ≤ 10 kWh/m²a**
- Ecological electricity contract <u>and</u>
- Electricity is generated by photovoltaic (including storage system) <u>and</u>
- High efficient infrared heating panels

Source: www.klimaaktiv.at

1. Modular Design: Air Ventilation System

Operating Principle





Source:blumartin, Lukas Krainz, Master Thesis 2018

1. Modular Design: klimaaktiv-Building Declaration

Bronze

523

von 1000 möglichen Punkten

- Gebäudedaten
- Standort und Qualitätssicherung
- Energie und Versorgung
- Baustoffe und Konstruktion
- Komfort und Raumluftqualität

Büro und Bildung 2017: MODUS 5.50 office 1000 523

	Gebäudedaten				
A	Standort und Qualitätssicherung	M	75	72	
A.1	Infrastruktur und Umweltfreundliche Mobilität	M	60	45	
A.2	Qualitätsnachweise für Planung und Ausführung	M	130	27	✓
B	Energie und Versorgung	M	00	281	
B.0	Auswahl des Energienachweisverfahrens				
B.1	Referenz-HWB (OIB) / Heizwärmebedarf (PHPP)	M	100	33	✓
B.2	Kühlbedarf (außeninduziert) / Nutzkältebedarf	M	75	38	✓
B.3	Primärenergiebedarf	M	75	27	✓
B.4	CO2-Emissionen	M	150	83	✓
B.5a	Gesamtenergieeffizienz-Faktor fGEE OIB		50	50	✓
B.5b	Erzeugung PV-Strom PHPP		50	0	✓
B.6	Weitere besondere Energieeffizienzmaßnahmen	M	145	50	✓
C	Baustoffe und Konstruktion	M	50	120	
C.1	Baustoffe	M	90	70	
C.2	Konstruktion und Gebäude	M	100	50	✓
D	Komfort und Raumluftqualität	M	75	50	
D.1	Thermischer Komfort im Sommer		50	20	
D.2	Komfortlüftung mit Wärmerückgewinnung		40	30	
D.3	Einsatz schadstoff- und emissionsarmer Bauprodukte / be Sanierung inkl. Schadstoffuntersuchung		80	0	✓
D.4	Messung der Qualität der Innenluft	M	40	0	✓

Source: Lukas Krainz, Master Thesis 2018

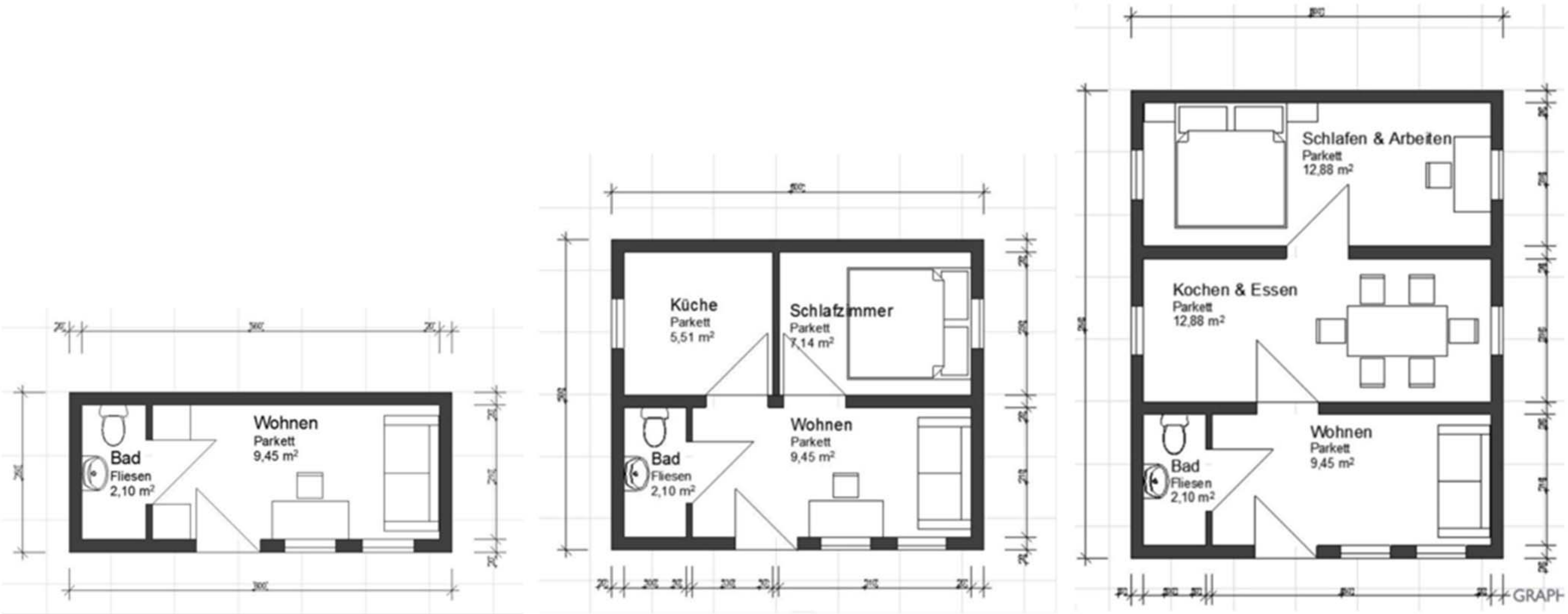
2. Energy self-sufficient cabin (Students project)

Goals of the Interdisciplinary Project:

- Theoretical elaboration on the topic of module construction and mobility
- Presentation of a concept draft with CAD plans
- Substitution of expensive and ecologically questionable building parts
- Optimization of the energy concept
- Efficiency calculations and comparison with other building concepts
- 3D-Visualization with VR glasses for virtual tour
- Construction of the cabin in cooperation with regional companies

Source: Leindecker et al. , Interdisciplinary Project, Upper Austria University of Applied Sciences 2017

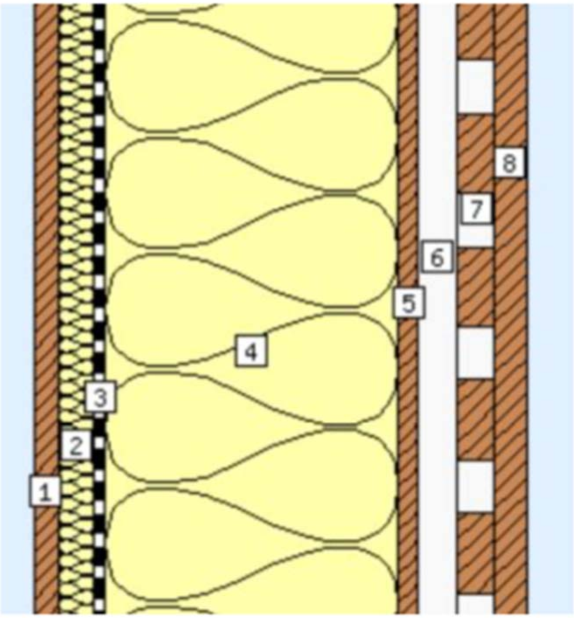
2. Energy self-sufficient cabin: Modular Design



Source: Leindecker et al., Interdisciplinary Project, Upper Austria University of Applied Sciences 2017

2. Energy self-sufficient cabin: Wall

Wall Construction



No.	Component	d [cm]	λ [W/mK]
1	Natural Wood Board	1,90	0,120
2	Installation Gap (with Insulation)	2,70	0,045
3	Vapor Barrier	0,10	0,230
4	Battens (20%), Insulation (80%)	22,00	0,045
5	DHF-Wood Fiber Board	1,50	0,100
6	Ventilation Battening	3,00	-
7	Counter Battening	2,70	-
8	Lintel Shuttering	2,40	-

U-Value = 0,21 W/m²K

Source: Leindecker et al., Interdisciplinary Project, Upper Austria University of Applied Sciences 2017

2. Energy self-sufficient cabin: Foundations

Screw-Foundations

Source: www.neuco.eu

- ✓ No time-consuming and cost-intensive excavation work
- ✓ Residue-free removal → preservation of the value of the building ground
- ✓ No destruction of soil ecology

2. Energy self-sufficient cabin (sample wall)

Power Supply: Two building integrated 50W mono-crystalline PV modules (serial, 24 V DC); 4 gel batteries monitored by a charge controller (capacity 34 Ah); inverter from 24V DC to 230V AC.

Single Room Ventilation Unit (with heat recovery): has the task to efficiently exchanging the used, low-oxygen and humid warm room air with the fresh outside air at a power consumption of 4-34 W. Compared to manual ventilation, 80 to 90 % of the heat is recovered.

Cardboard Honeycomb Insulation: Passively uses solar radiation for heat generation (winter); prevents overheating (summer); in the best case negative dynamic U-value and an average U-value of 0 W/m²K is possible.

Wall Construction

Heat supply: Infrared heating panel under Bio-Vinyl floor; power supply self-sufficient via own photovoltaic system; pleasant room climate; supply voltage 24 V; ideal for small temporary heated buildings

Source: Leindecker et al., Interdisciplinary Project, Upper Austria University of Applied Sciences 2017

Energy self-sufficient cabin: Costs

Costs for a cabin with 100m² (example)

Costs (ready for expansion) = 1.400 €/ m²

(incl. doors, windows, façade and roof exterior finished; interior ready for expansion)

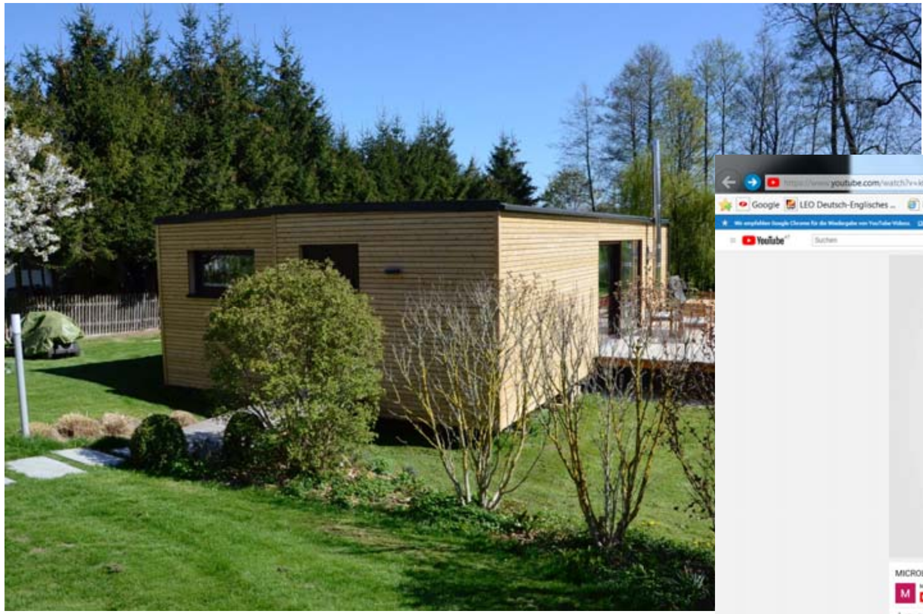
Costs (turnkey) = 2.160 €/m²

(incl. doors, windows, parquet flooring, facade, roof, electrical installation, sanitary installation and all walls painted white)

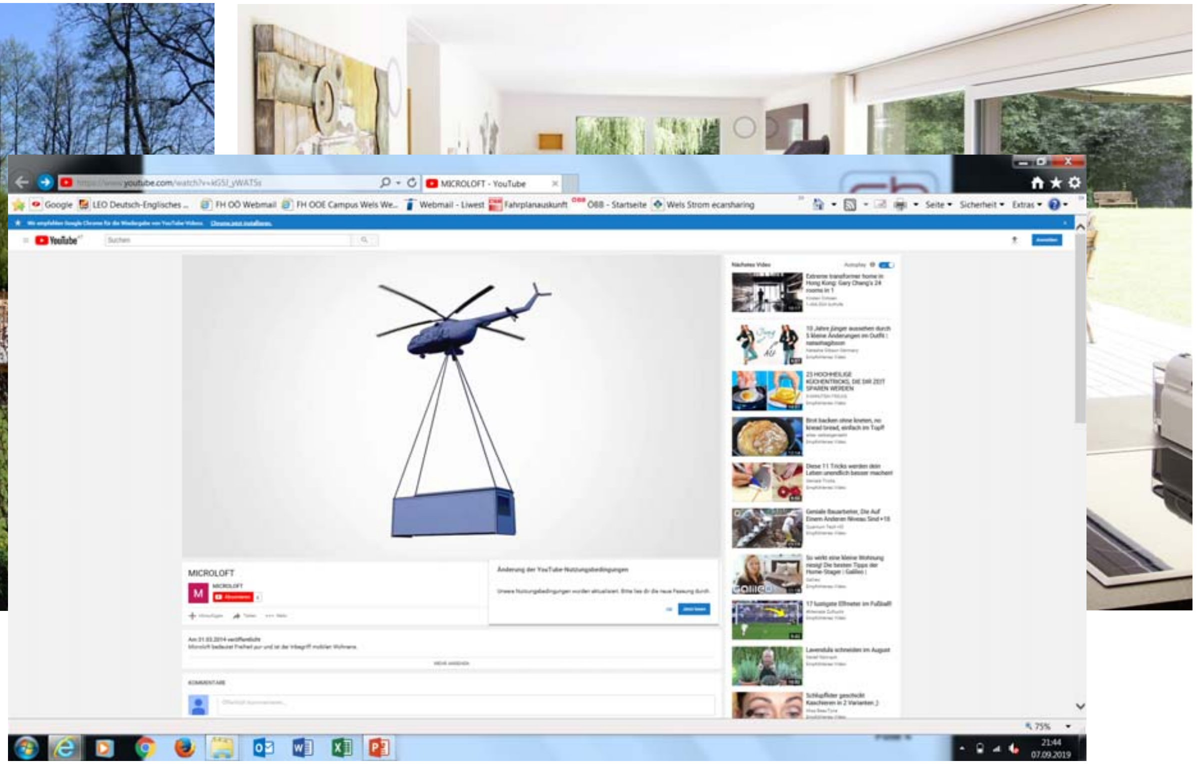
Source: Leindecker et al., Interdisciplinary Project, Upper Austria University of Applied Sciences 2017

3. Practical Example

microHome (Genböck Haus); microloft



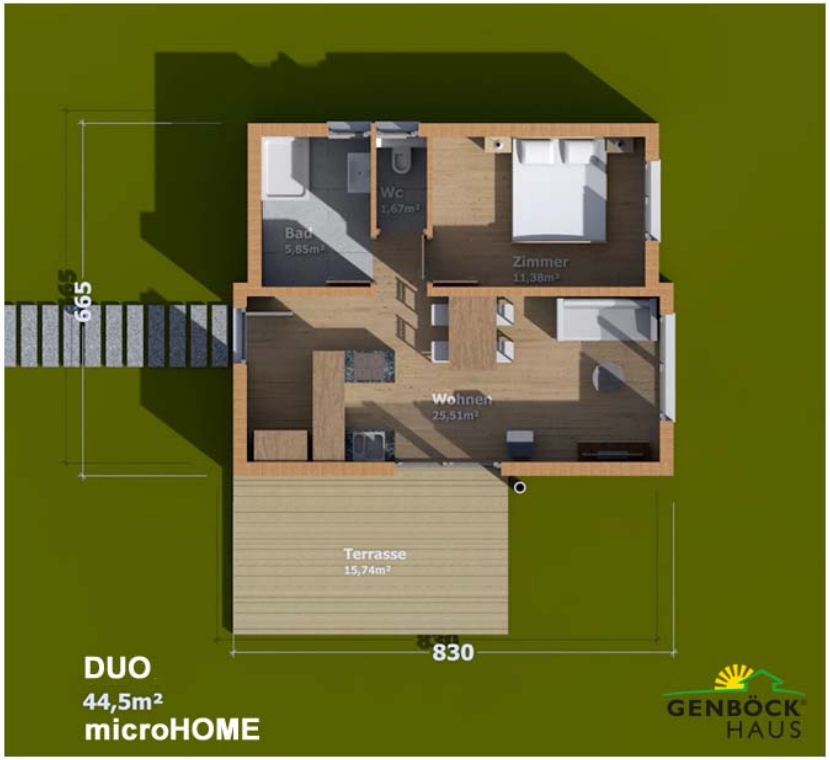
Source: www.genboeck.at



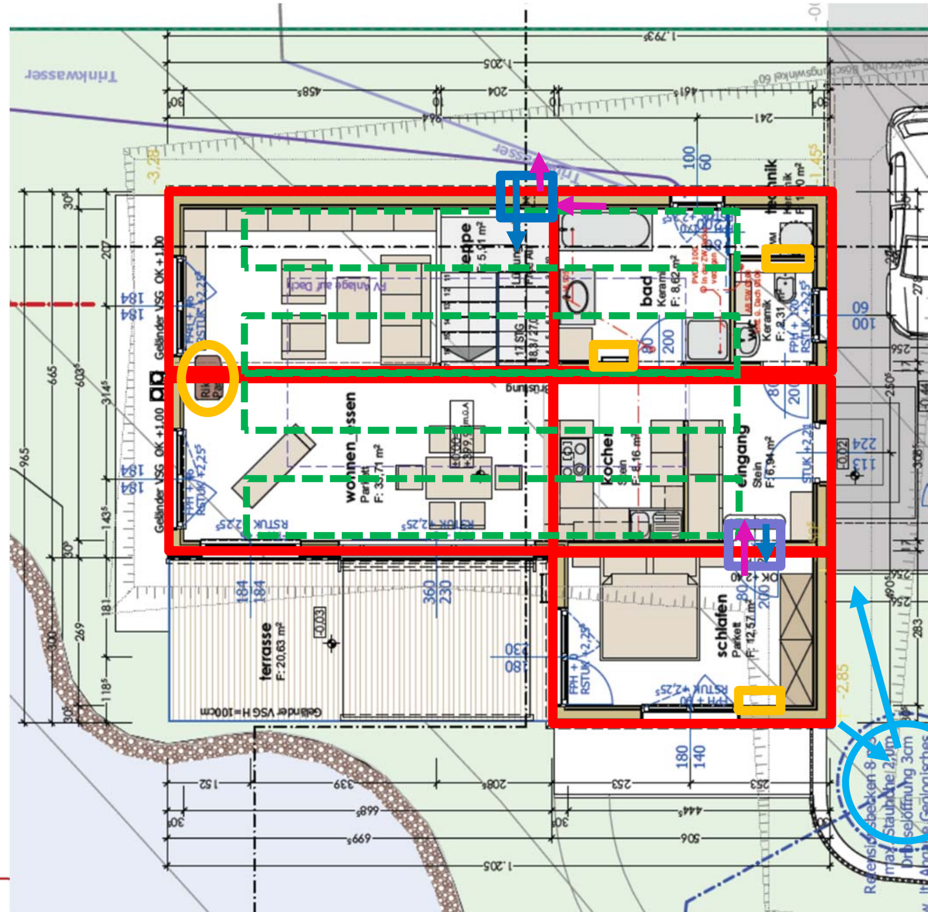
Source:
https://www.youtube.com/watch?v=kG5J_yWAT5st

3. Practical Example

microHome (Genböck Haus)
2 moduls



microHOME (Leindecker, „extended version“), 5 moduls



Source: www.genboeck.at

3. Practical Example: Assembling the Moduls

microHome (Leindecker)

Video (1:10 min.)

VID-20181121-WA0000.mp4

3. Practical Example: First Floor finished

microHome (Leindecker)

3. Practical Example: cost-effectiveness

	Euro	Euro/m2
microHOME Modul (first floor, 79,42 m2)	153.566,-	1.934,-

(included: electrical and plumbing installation, ir heating backup bathroom+toilet)
(not included in-house efforts: filling and painting of plasterboards, flooring, tiling, internal doors, terrace)

basement for microHOME (58,63 m2)	62.146.-	1.060,-

(special foundation, reinforced concrete ground plate, walls, columns, beams, retaining wall)

relevant equipment:

automated pellets/billet stove (main heating system)	6.650.-	
photovoltaic system 6 kWp (prepared for battery)	9.447,-	(without subsidy)
rainwater utilization, cistern 10 m3	7.440.-	

Source: privat

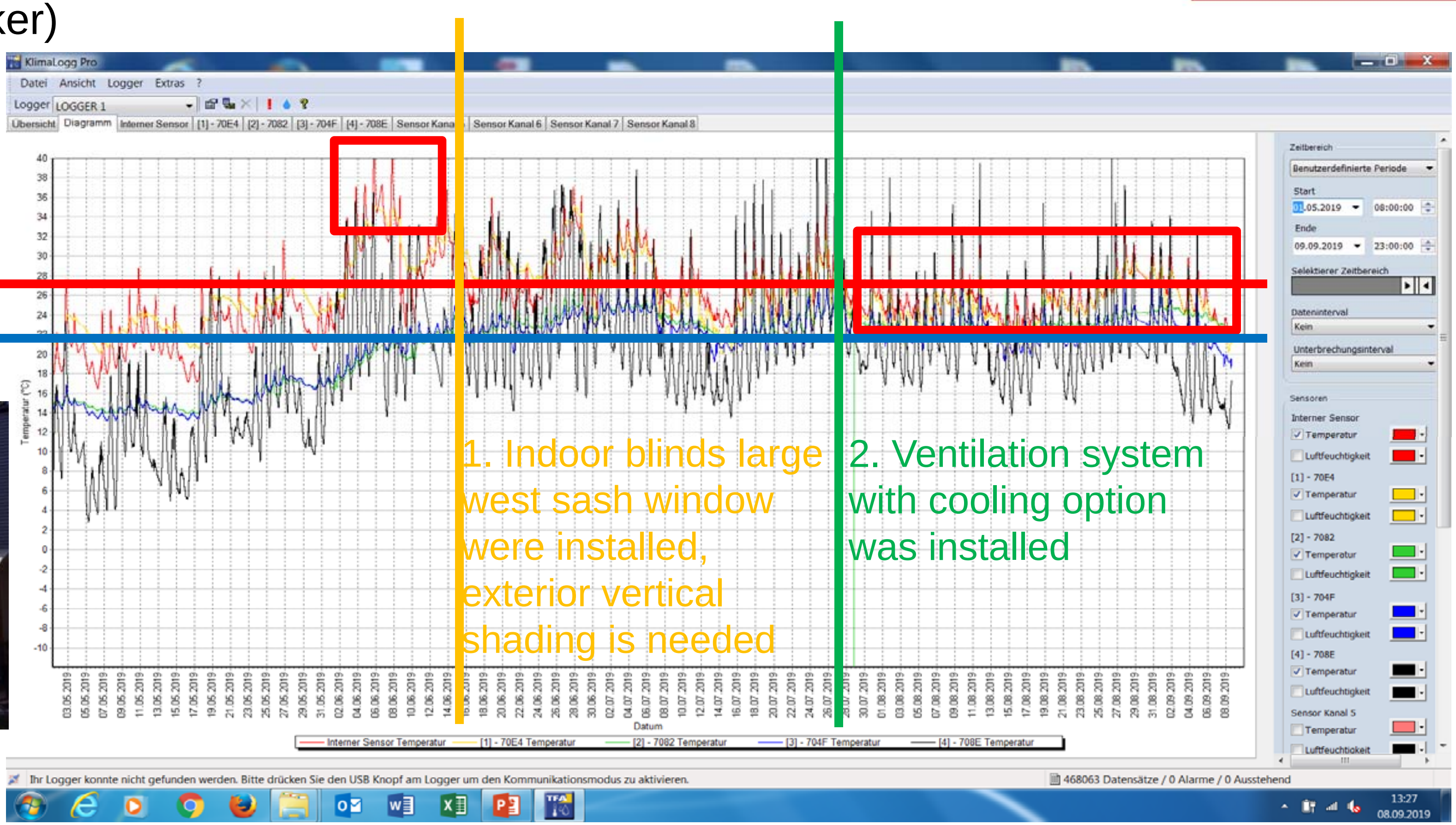
3. Practical Example: Indoor Air Quality in Summer

microHome (Leindecker)

Indoor Air Measurement: extrerior shading is not completed (sun sails)

26°C

20°C



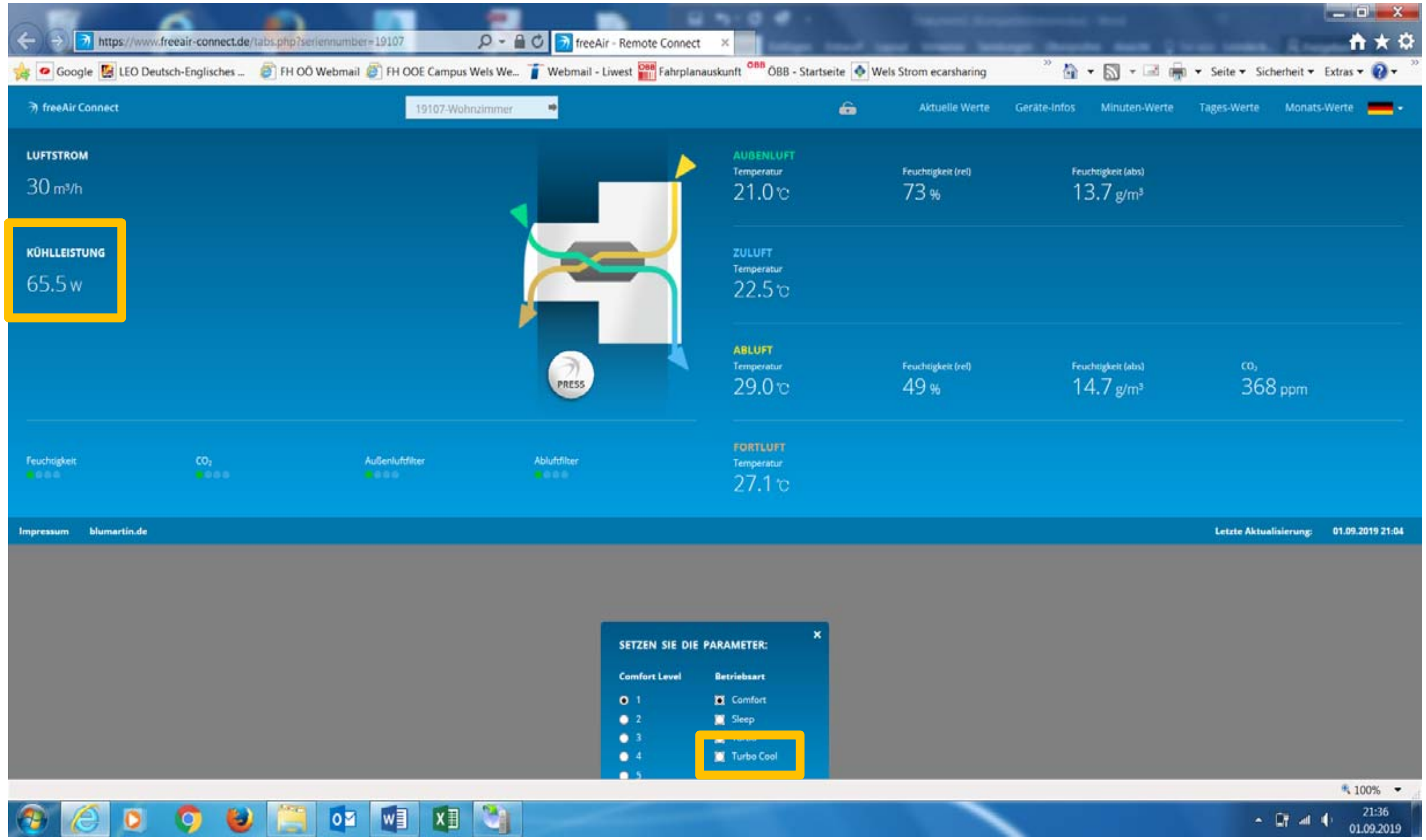
Source: privat

3. Practical Example: Ventilation System

microHome (Leindecker)

Decentralized Ventilation System with heat recovery and cooling option

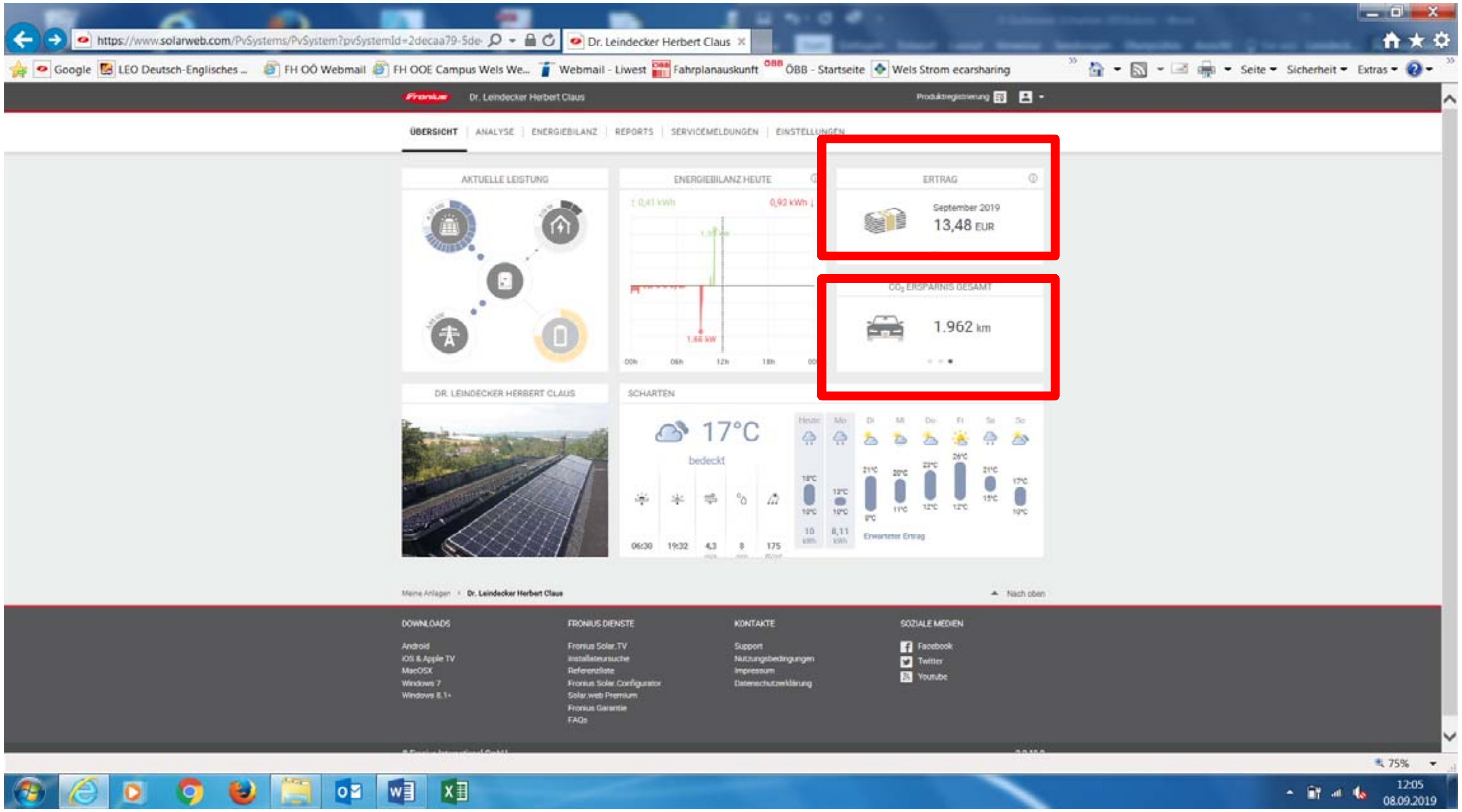
Source: privat



3. Practical Example: Photovoltaic facility

microHome (Leindecker)

PV Overview

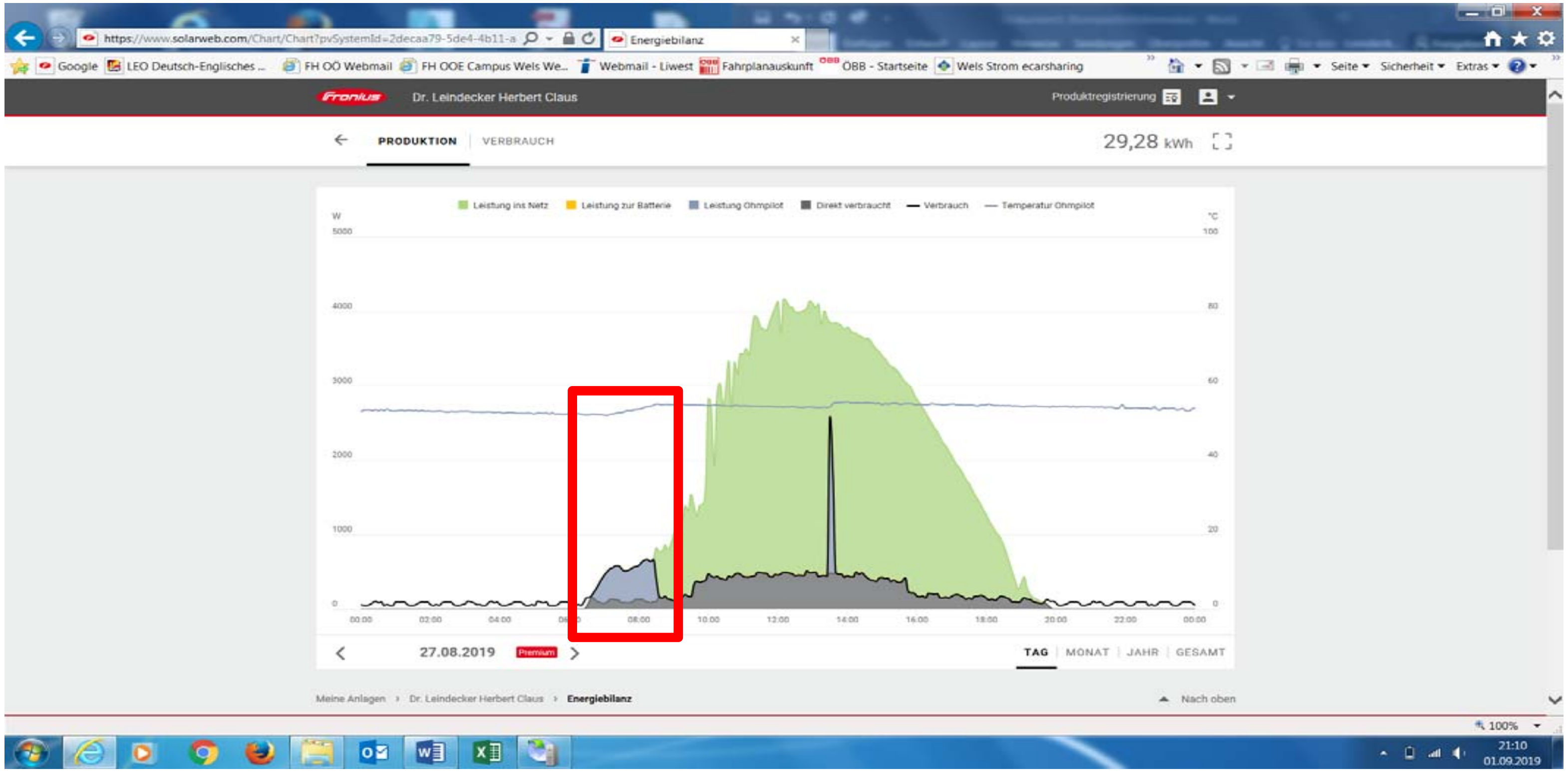


Source: privat

Practical Example: Photovoltaic Monitoring

microHome (Genböck Haus, Leindecker)

PV typical Day: heating the warm water boiler



Source: privat

Conculsions

- Mobility of houses is a most interesting topic
- Mobile homes offer the possibility of renting land for a temporary period of time
- Prefabrication, flexibility, sustainability and sufficiency are becoming increasingly important, facing a steady rise in real estate and building prices
- The flexible use of small residential modules offers new possibilities for structural redensification in urban areas and use of vacancy (inner courtyards, rooftops…)
- These projects show that modular based building concepts can be produced and operated in a sustainable, economical and “affordable” way

Removable PopUp dorms Seestadt Aspern

Sigurd Larsen: modular houses on the rooftop of concrete blocks in Berlin

Contact Information

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Event Information

Datum: Dienstag, 26. November 2019
Dauer: 09:00 bis 13:00 Uhr
Veranstaltungsort: FH OÖ Campus Wels, Fakultät für Technik und Angewandte Naturwissenschaften

Thank you very much for your attention!