INTERNATIONAL FORUM FOR CLEAN ENERGY TECHNOLOGIES

BIPV VIA SMART GRID, HEAT PUMPS THERMAL USE OF UNDERGROUND AND ABANDONED MINES ENERGY STORAGE FOR LARGE-SCALE RES UTILIZATION

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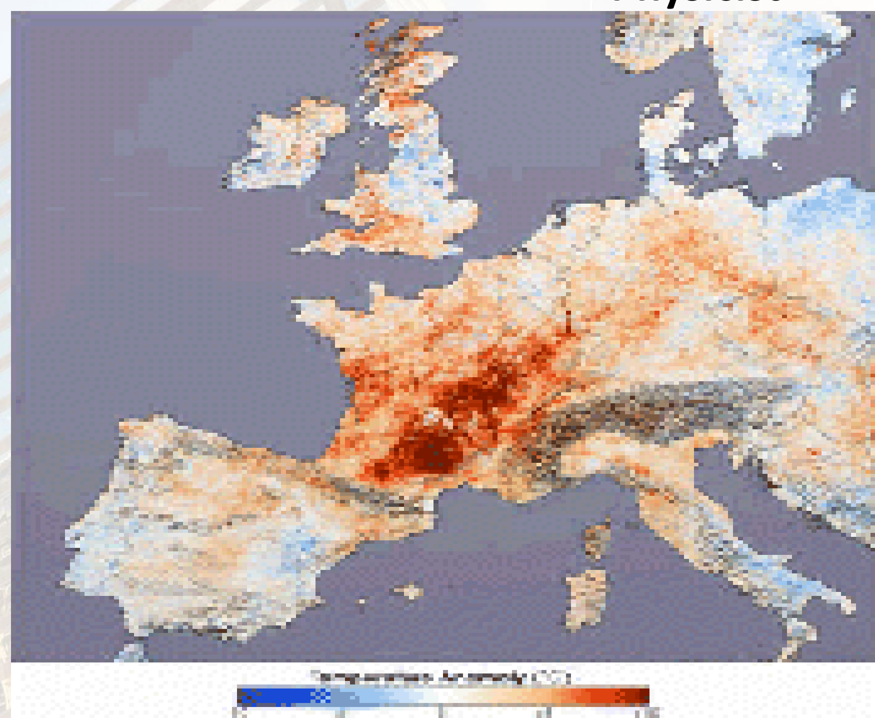
Novi Sad, 29-30, October 2019

Global Warming as Result of Global Disharmony or..?

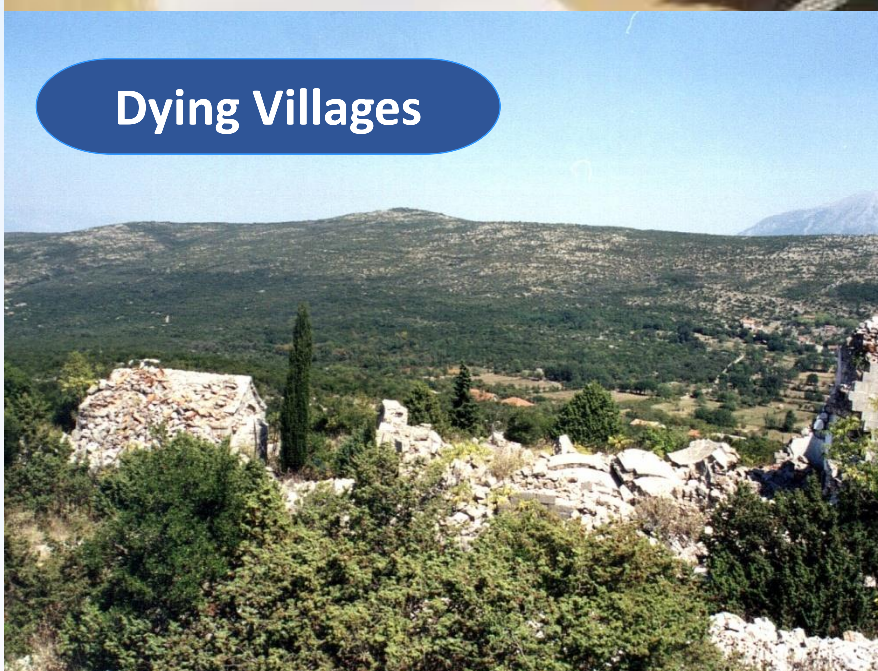
- Mathematical theory of climate & Ice ages.
- A need for cooling and Air-conditioning of buildings in extreme growth.
- Jiri Grygar astrophysicist – Whence Carbon Big Bang and Space Expansion

Milutin Milankovic 1879-1958, Ice Ages Theory

Whence carbon? Clima 2013 Jiri Grygar Astro-Physicist



Weather Extremes - Catastrophic Events



EU Directives On The Buildings Energy Performance

The 2002 and 2010 Directives, all Member States did get new energy efficiency requirements for existing and new buildings in their building codes.

Expectation was that the EPBD will establish a good framework for improving energy performance in buildings and that it will raise awareness on energy efficiency resulting in significant reduction of buildings energy use.

Brussels, 30.11.2016 COM(2016) 765 final 2016/0381 Proposal for a ***DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL***

amending Directive 2010/31/EU on the energy performance of buildings outlines that the most important DIRECTIVES result is

- **Its contribution to 2030 and 2050 energy and climate targets was recognized.., but among the Results disscussed nearly ZE Buildings,..and there are possible Net ZEB & EnPlusBuidings!**

DIRECTIVE Official Journal of the EU 21.12.2018

DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC with the

***Annez VII* ENERGY FROM HEAT PUMPS (HP) AS RES -** Aerothermal, geothermal or hydrothermal energy captured by heat pumps to be calculated in accordance with the following formula:

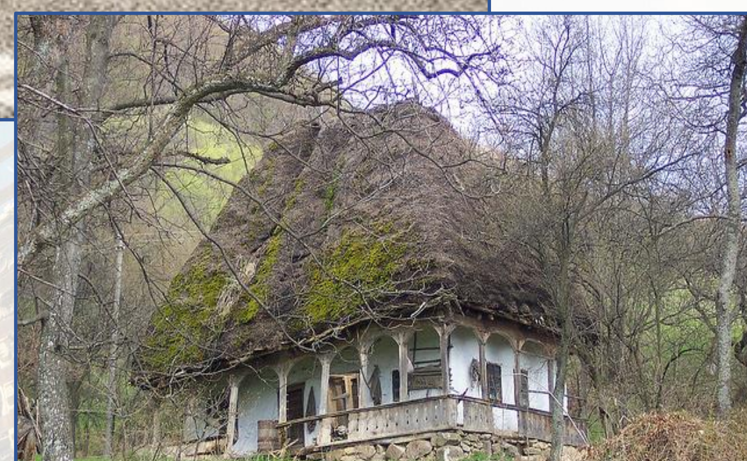
ERES = Qusable * (1 – 1/SPF)

— fulfilling the criteria: Only heat pumps for which SPF > 1,15 * 1/η shall be taken into account,

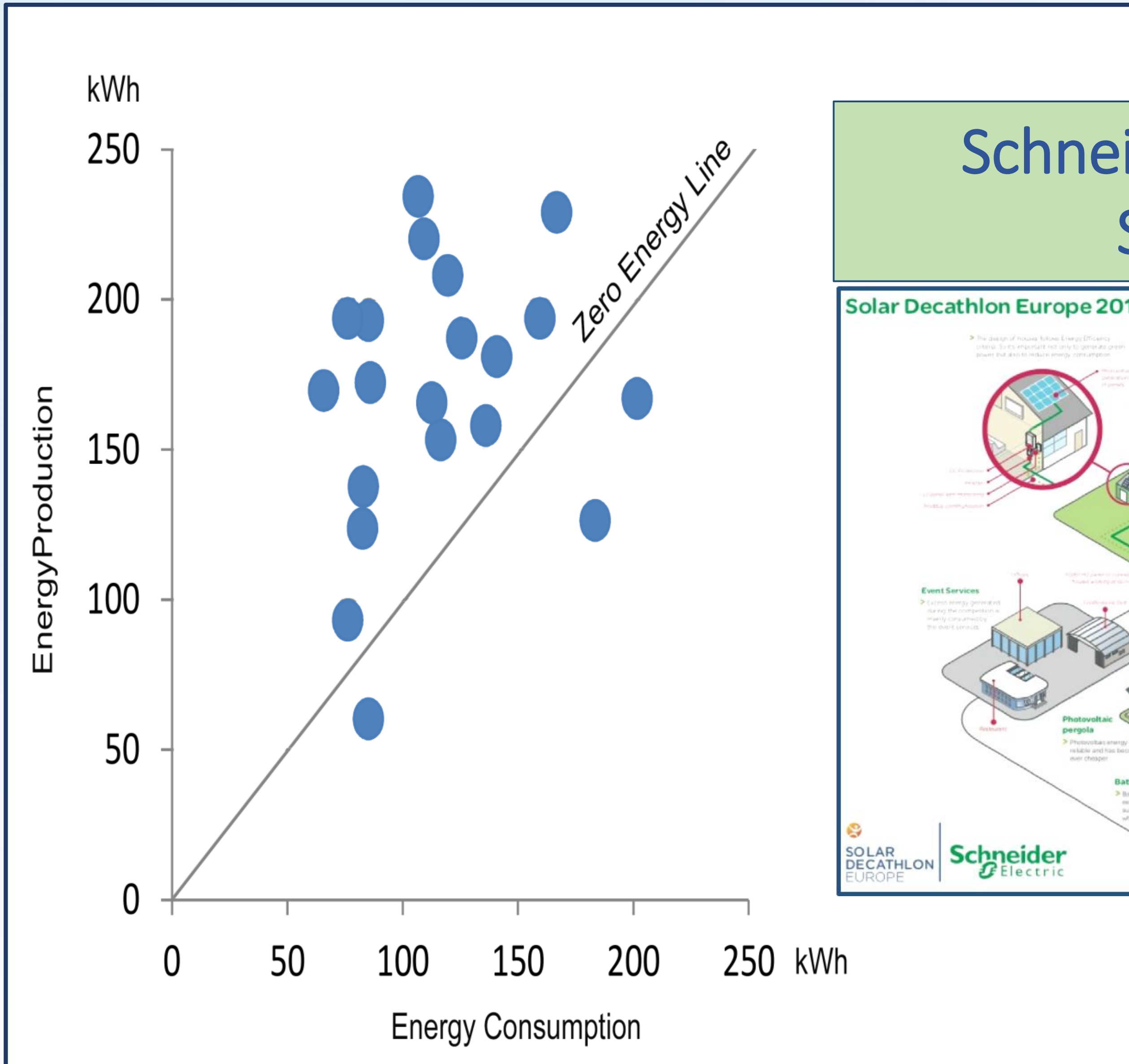
— **SPF Seasonal performance factor for those heat pumps**,

— η = the ratio between total gross production of electricity and the primary energy consumption

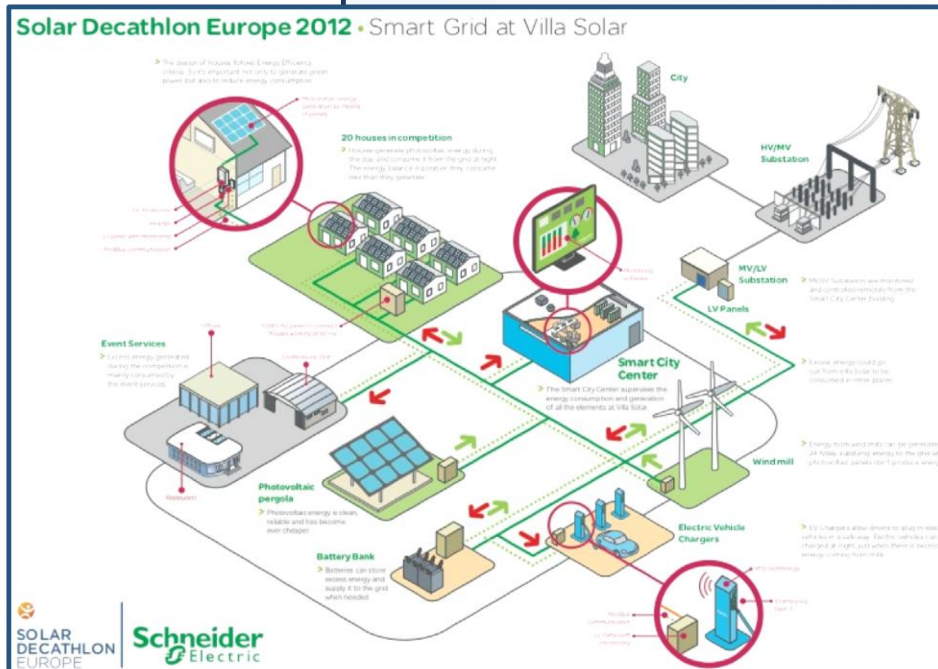
Hungary's ODOO Solar Decathlon Europe 2012 Madrid & SDE 2014 BUC Prispa From Romania in Paris



Solar Decathlon 2014 Energy Balance



Schneider Micro grid – Smart Grid



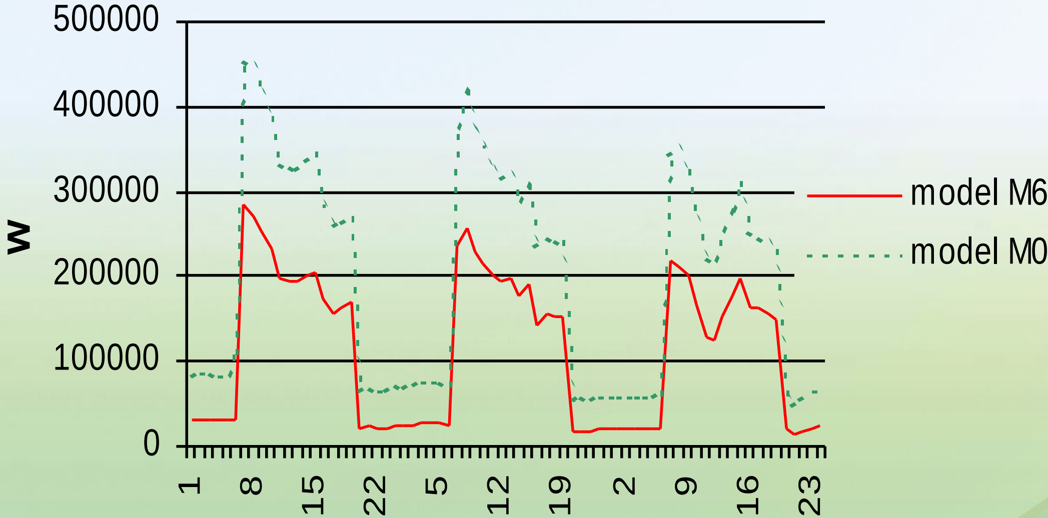
To Reach NZEB Status of New or Refurbished Building

RES integrated energy system's efficient and economical introduction must be preceded by the:

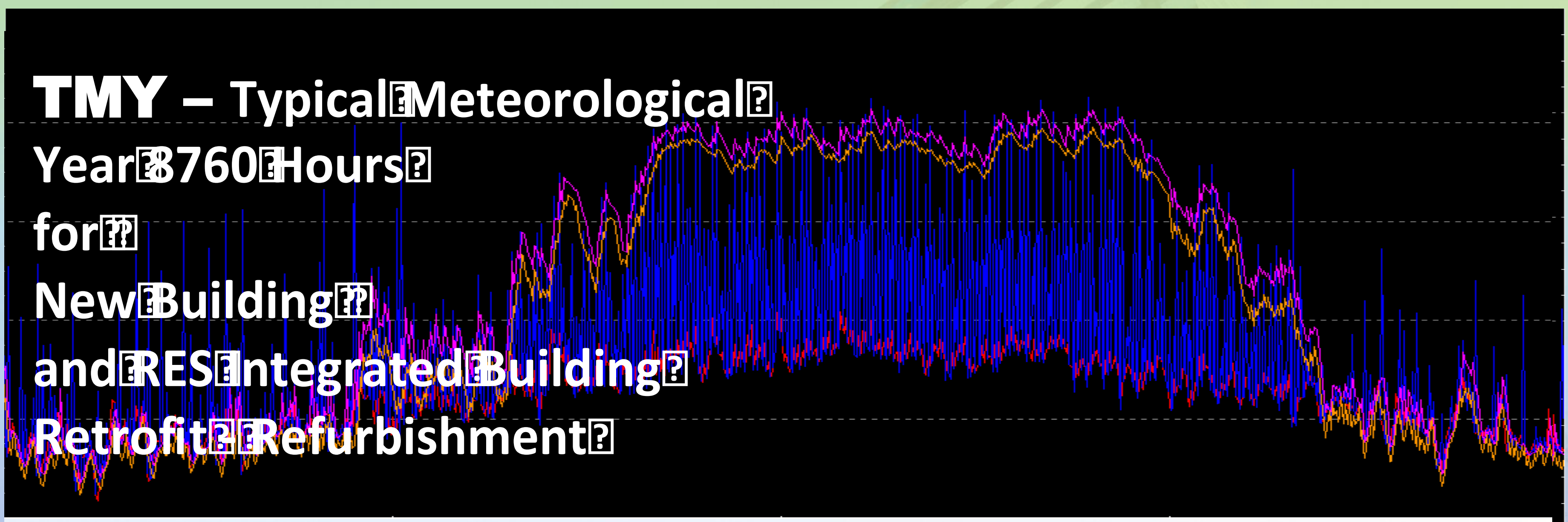
- **Energy efficiency optimization to the level of minimum energy demands** - achieved by the aggregate application of all known available measures and in scientific search for new:
  - knowledge,
  - technologies and
  - energy efficient systems and equipment.
- Role of science and new IT knowledge and technologies:
  - **Particularly in construction sector can be crucial.**
  - **Loads and demands prediction and control**
  - Distributed energy generation & storage with the utilities energy production and distribution harmonization - Smart grid control – realization

Building's Energy Loads Minimization via BPS

BPS (Building Performance Simulation)



TRNSYS
DOE2 SERIES
VISUAL DOE
ENERGY PLUS, ESP-r
DesignBUILDER, APACHE, TRACE
ADELINE – RADIANCE
SPARK, IDA ICE
CFD – PHOENICS, CFX, FLUENT

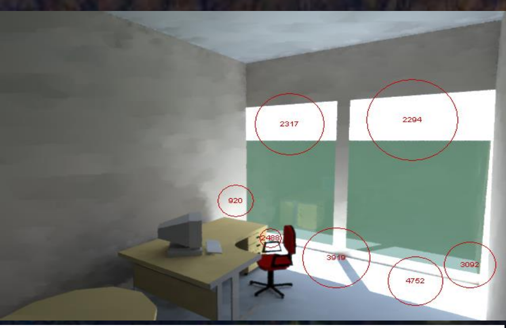


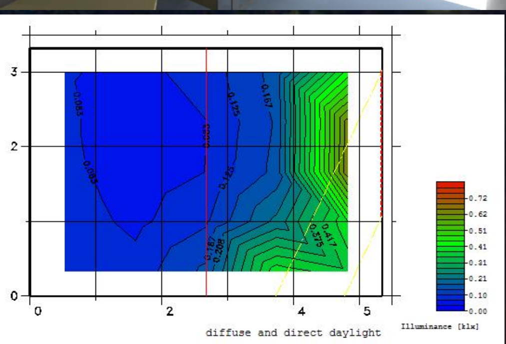
TMY – Typical Meteorological Year (8760 Hours)
for
New Building
and RES Integrated Building
Retrofit – Refurbishment

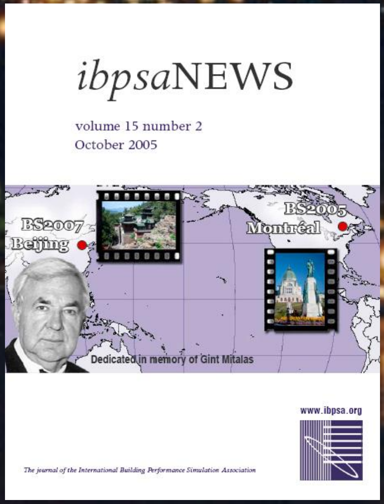
USCE Tower Reconstruction and Refurbishment

Energy demand reduction
For Heating 60% &
For Cooling 75%

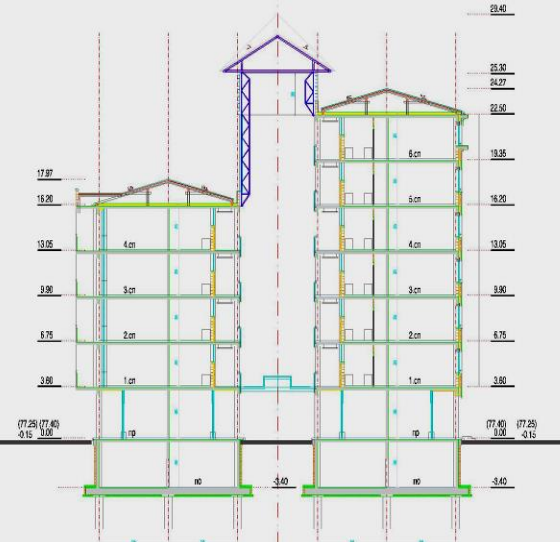
Success Stories in BPS and Energy Efficiency Optimization

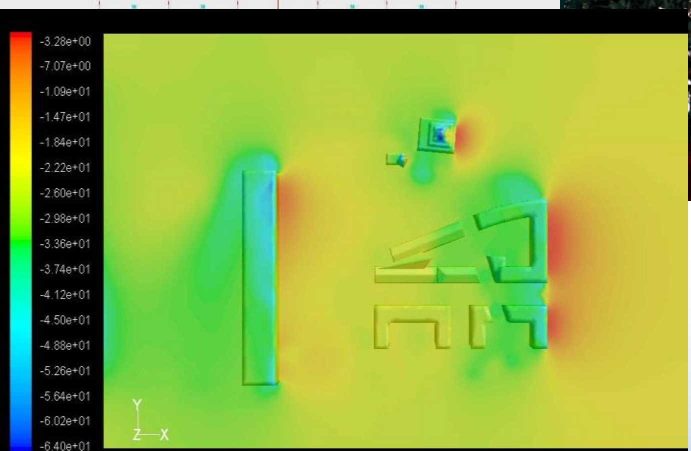


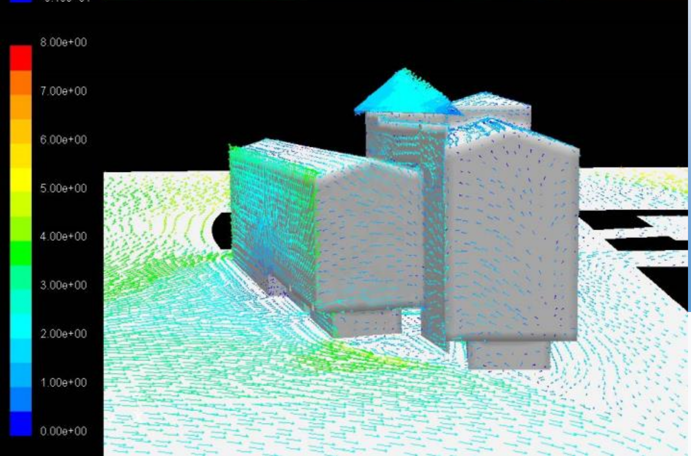


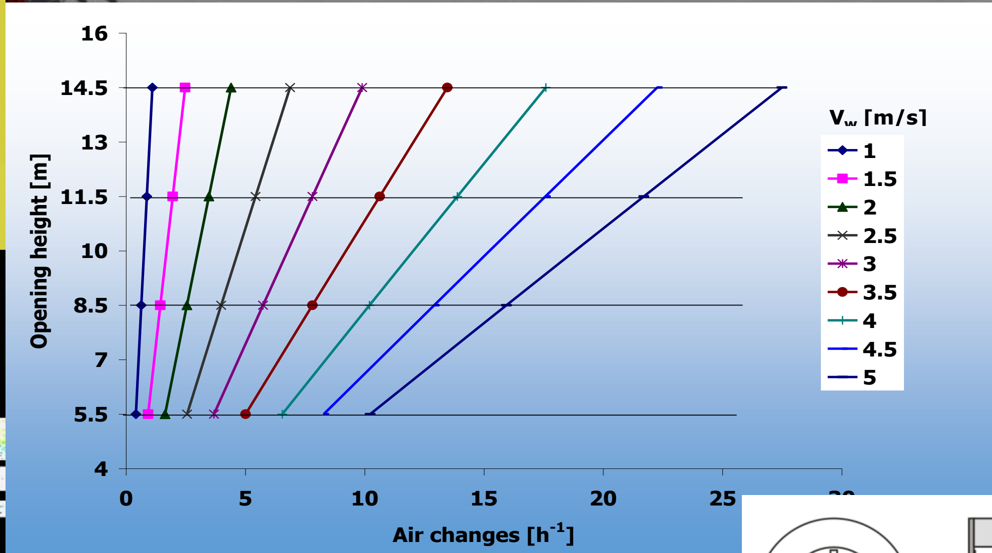


Residential Building Mixed Ventilation Optimal Control
PV Powered

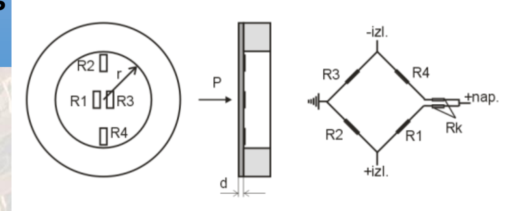


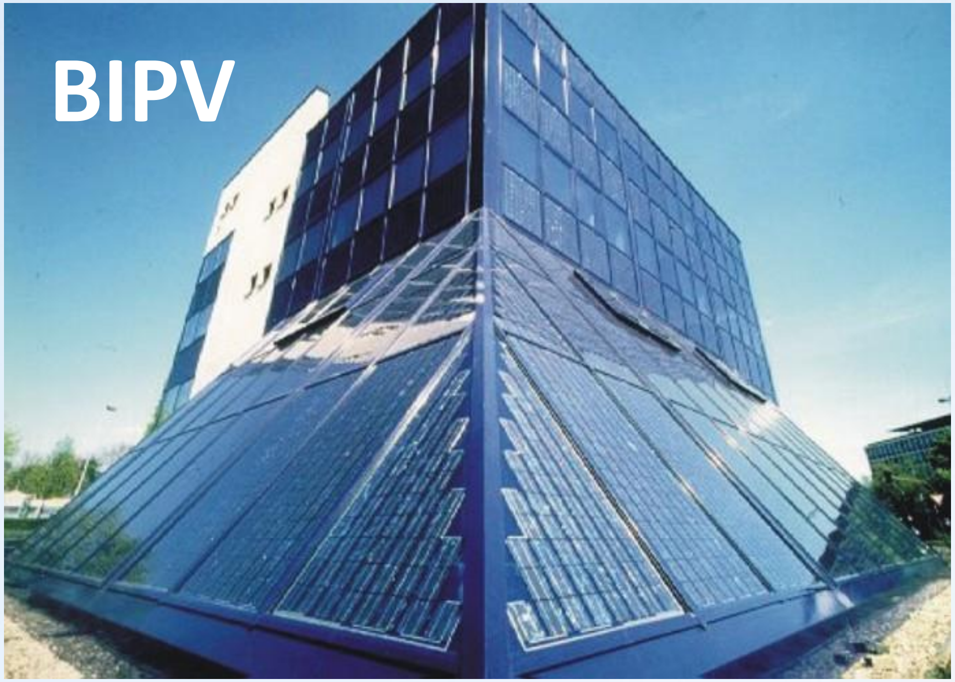


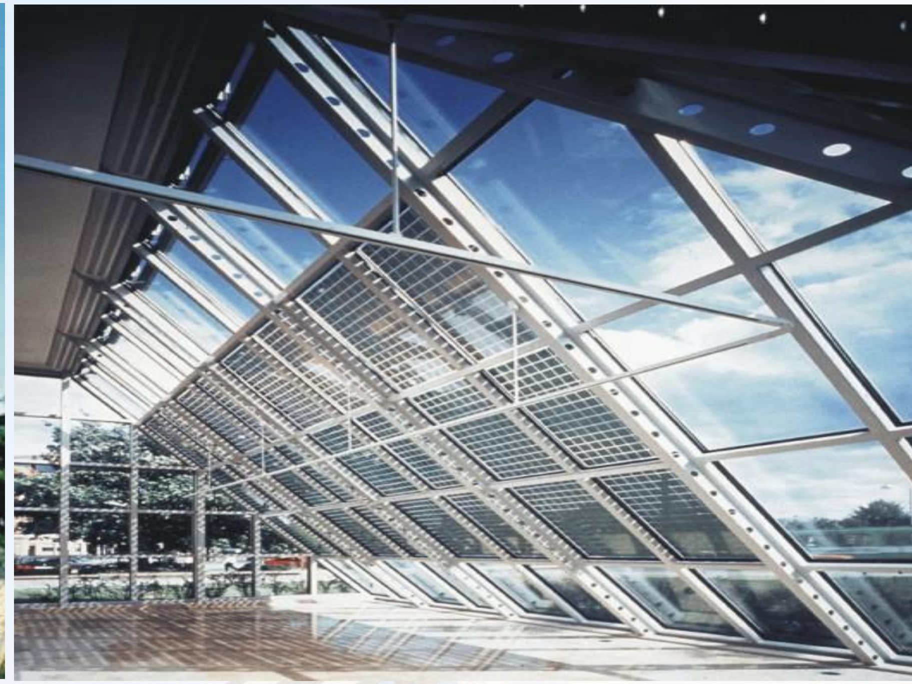




Low pressure difference sensor




BIPV




Semitransparent PV glazing

BIPV vs PV: a non standard component

Swiss BIPV focus

- Planning regulations against urban sprawl
- PV power plants prohibited
- Exclusive integration into built environment
- BAPV: 75%, BIPV: 25%
- **No PV power plants in Switzerland**
- **PV integrated only in buildings**
- Architectural Design as innovation
- Demonstration of PV into various building envelope elements
- **ZEB performance validation through measurements**
- **BIM for modeling and planning**

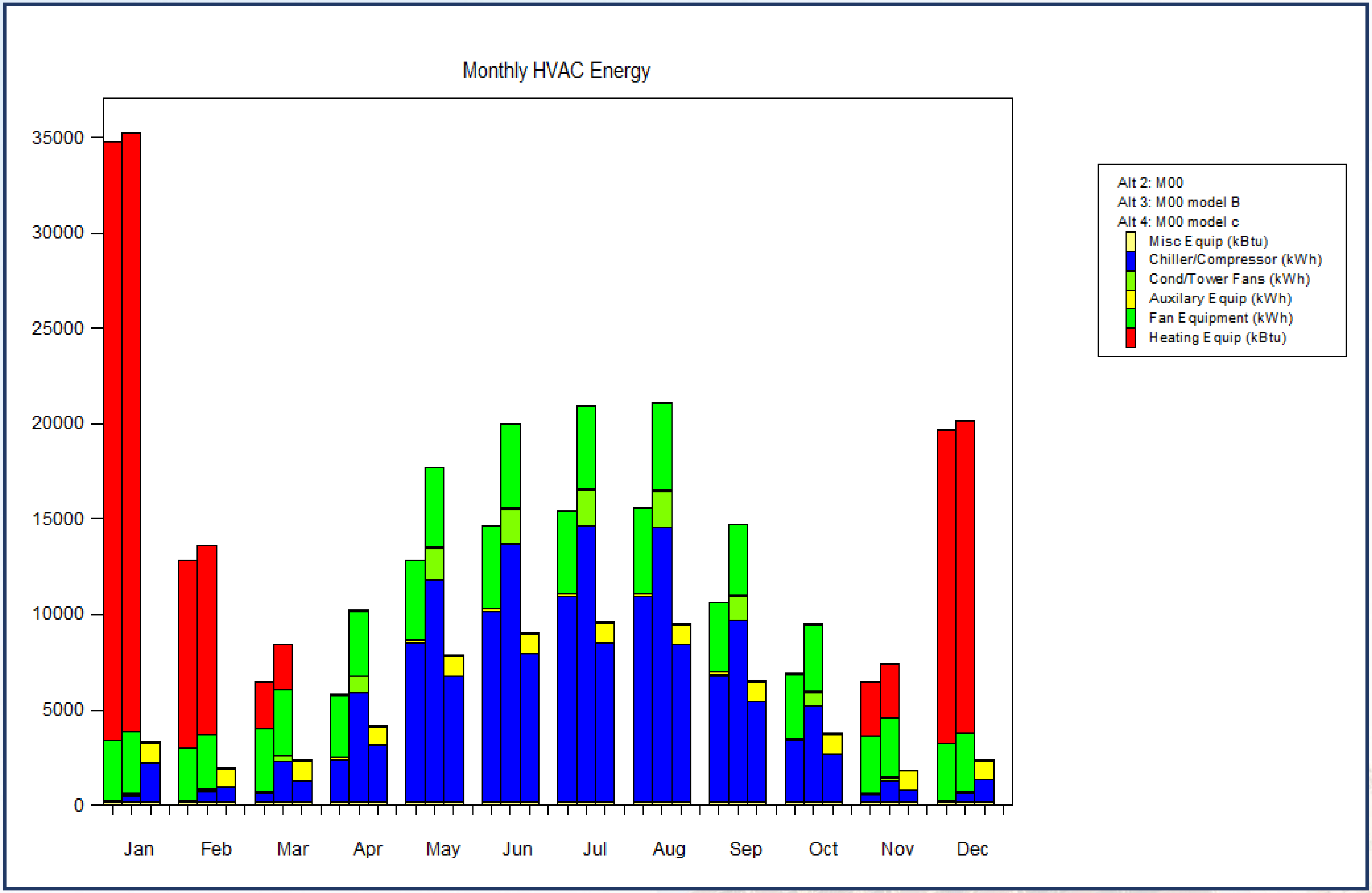
Peri-urbanized development (RURBAN)

- **Swiss Harmonized Rural and Urban Development**
- **Peri-urbanization**
- **RURBAN** development relates to those processes of dispersive urban growth creating hybrid landscapes of fragmented urban and rural characteristics, as for example in Switzerland.

Historic Belgrade Center

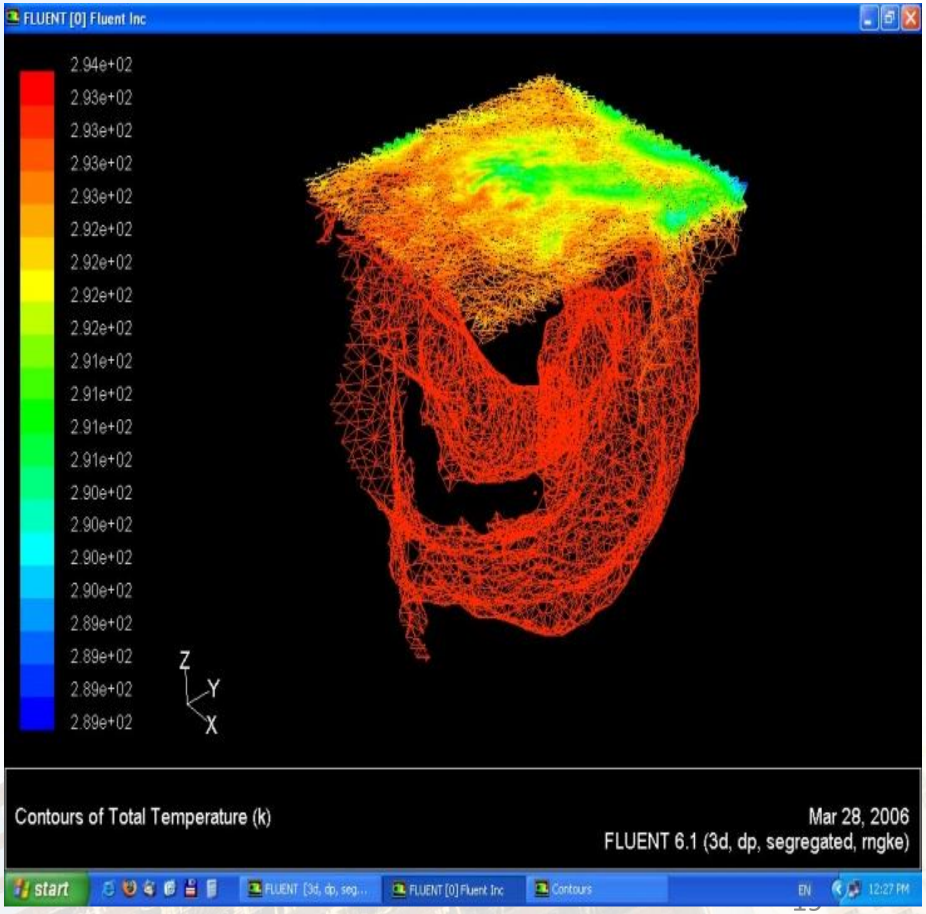
Envelope Models		MO0	MO0.1	MO1	MO1.1	MO2
Heat losses [W]	-18[°C]	155000	88000	59000	44000	43000
	-12[°C]	132000	77000	51000	38000	38000
q_{sp} [W/m²]	-18[°C]	72	41	27	20	20
	-12[°C]	62	36	23	17	17
q_{sp} [W/m³]	-18[°C]	23	13	9	7	6
	-12 [°C]	21	12	8	6	6
Qh ventilation air [kW]	-18[°C]	143000	143000	143000	143000	143000
	-12 [°C]	135000	135000	135000	135000	135000
Total heating load [kW] for -18[°C]		298000	231000	202000	187000	186000
Total heating load [kW] for -12[°C]		267000	212000	186000	173000	173000
Heat Gains [W]		143000	128000	131900	112000	101000
q_{sp} [W/m²]*		70	63	65	55	50
q_{sp} [W/m³]		21	19	20	17	15
Cooling heat for vent. air [kW]		163000	163000	163000	163000	163000
Total cooling loads [kW]		306000	291000	294900	275000	264000

Monthly Energy Demand for HVAC System



Thermal Use of Underground with Heat Pump GSHP & GWHP

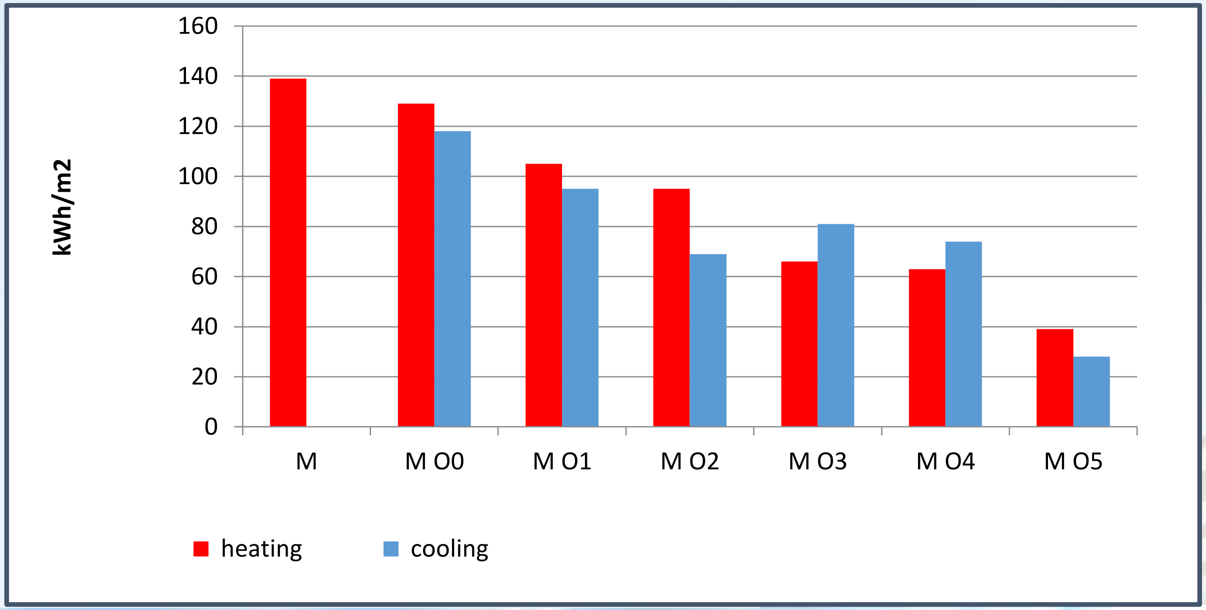
CFD Water Extraction & Intrusion Flow Field Analysis



investment values of the selected equipment of the Primary HVACS with nominal thermal H & C loads

Equipment Specificatioons & Invetment Values	INVESTMENT VALUES OF THE SELECTED EQUIPMENT OF THE PRIMARYHVAC & R SYSTEMS WITH NOMINAL THERMAL LOADS OF HEATING AND COOLING (kW)/Qh (kW)				
	1a.MO0-18^{0}C 298/306	1b.MO0-12^{0}C 267/183	5b.MO2-12^{0}C 173/158,4	5c.MO1-12C 173/158,4	
Heating: Primary & secundary substations with heat exchanger of District Heating System	Power 300 kW 380.000 Din + 300.000 Din **680.000 Din**	Power 300 kW 380.000 Din + 300.000 Din **680.000 Din**	Power 200 kW 320.000 Din 250.000 Din **570.000 Din**		
Cooling; Aic cooled Chiller Airtrend	Capacity: 320 kW 39.024 EUR= **4.604.832 Din**	Capacity: 184kW 24.754 EUR= **2.920.972 Din**	Capacity: 163 kW 21.763 EUR= **2.568.034 Din**		
Total	**5.284.832 Din**	**3.600.972 Din**	**3.138.034 Din**		
Heating 5b - EH: Electrical boiler; ACV Electrical boiler E-tech P 201 (200kW)			Capacity: 200 kW E-tech P 201 (200kW) 7.700 EUR= **908.600 Din**		
Cooling: Air cooled Chiller Airtrend			Capacity 163 kW 21.763 EUR= **2.568.034 Din**		
		Total	**3.476.634 Din**		
Heating; 60/40% HP/ElB: Air heat source – BEOHAMEX Frost HP VEGA H 110				HP- 108,8 kW 17.000 EUR= **2.006.000** **Din**	2 pieces E-tech 36 (72 kW) 640 EUR= **75.520** **Din**
Cooling 60/40% HP Air/Air, BEOHAMEX Frost HP VEGA H 110 **Chiler** with air heat sink CGA 240 BE LA					CGA 240 BE LA 62,1 kW 8.742 EUR= **1.031.556 Din**
			Total	**2.006.000**	**1.107.076**
			Total	**3.113.076 Din**	
Total 60/40% HP/ElB: Hydra WH100 BEOHAMEX Frost				HP- 107 kW 18.000 EUR= **2.036.0000 Din**	2 pieces E-tech 36 (72 kW) 640 EUR= **75.520 Din**
Cooling 60/40% HP Air Chiler Hydra WH100 BEOHAMEX Frost HP or Or Panklima CGA 240 BE LA					Air Chil CGA 240 BE LA 62,1 kW 8742 EUR= **1.031.556 Din**
According to 5.3.3. Hidro-geo section 1.426.000			**Total**	**2.036.000**	**1.107.076**
Zajedno sa Hidro-geo Ukupno	**4.569.076**			**3.143.076 Din**	

Deep Energy Refurbishment Social Housing in Belgrade

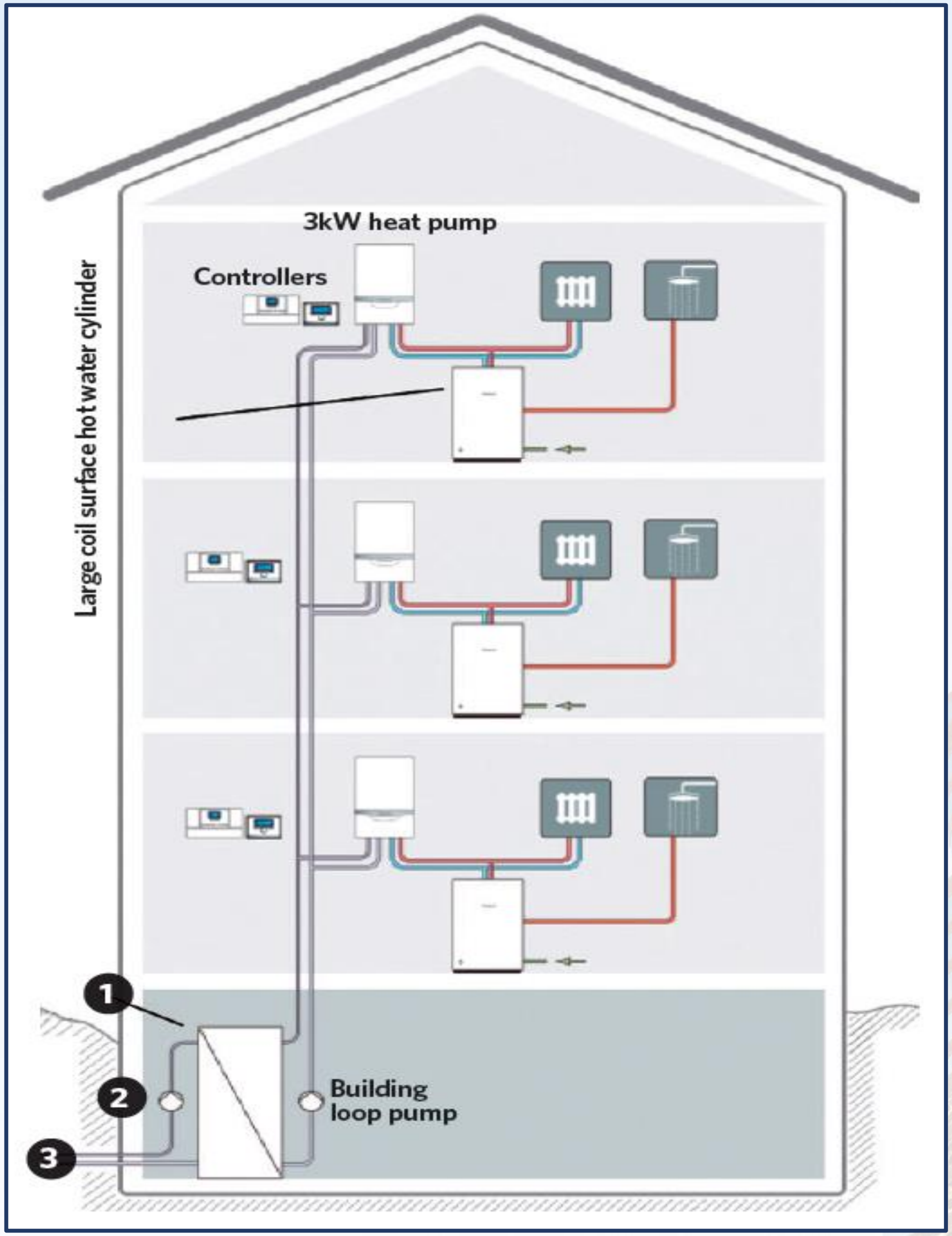


Opaque PV panels and/or Semitransparent Façade's Second Skin

Total installed PV 180.2 kW – 1/3rd of could power all existing AC split units in building

Total useful living area	**m^2**	**3.302.895**
Total heating energy used annually before project implem.	MWh	412.861,893
Total heating energy used annually after project implem.	MWh	137.620,631
Annually saved heating energy	MWh	275.241,262
Consumption of heating energy before and after the retrofit – envelope and construction energy efficiency improvement	kWh/ m^2 annually	120/40
Installed PV panels area/power	m^2/MW	412.000/57
Annually produced PV electricity	MWh	29.063,430
Building construction retrofit 30 – 60 € / m^2	1.302.895 x 30 1.302.896 x 60	99.086.860 198.173.700
BIPV PV panels costs estimate	412.000 x 200 €	82.400.000 €
Total Investment Estimate	€	181.986.860 to 280.573.700 €

Distributed mini HPumps with Shared Ground Loop

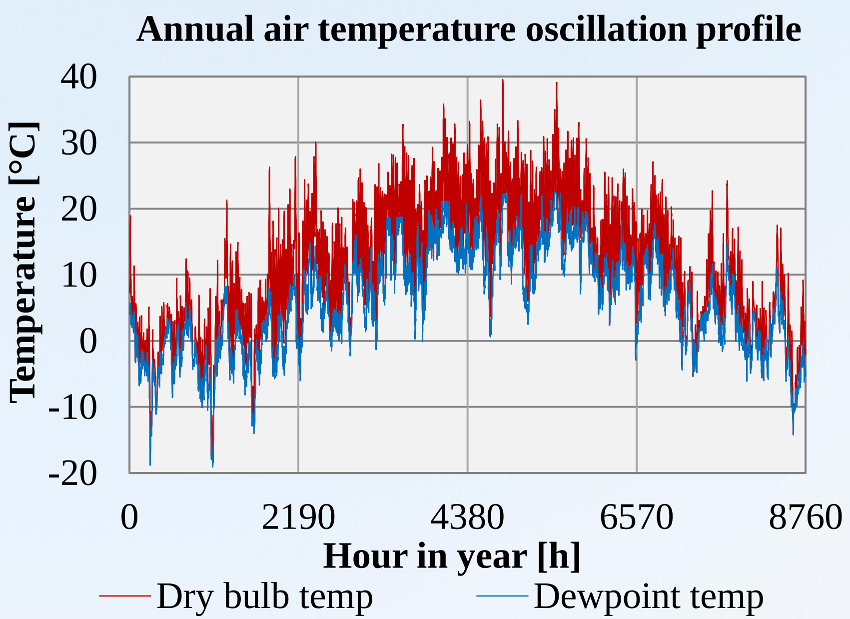


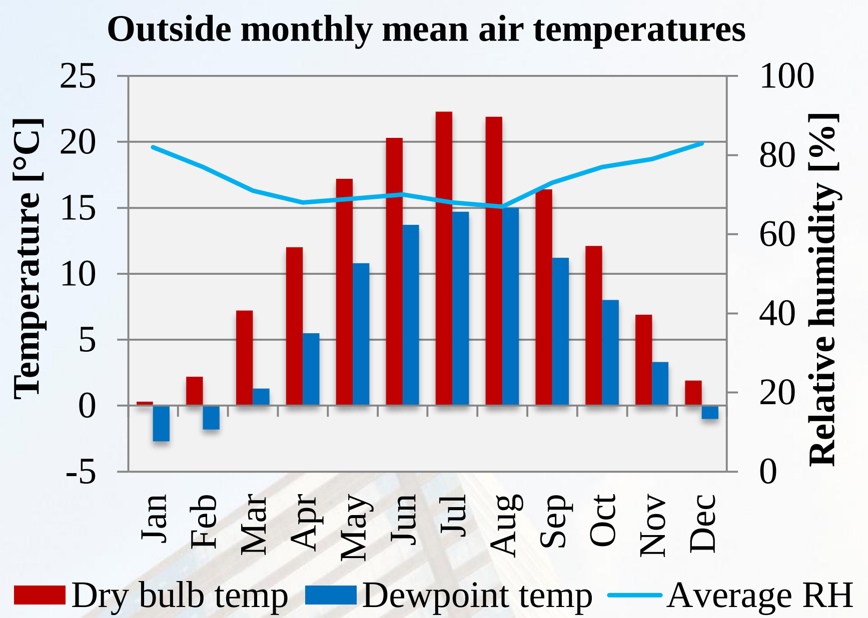
1-Plate heat exchanger
2-Ground loop pump
3-To and from ground loop

GWHP in Energy Refurbishment of an Old Traditional Village House to Approach Zero Fossil Energy and Healthy IEQ Status




Weather Data - Ćuprija

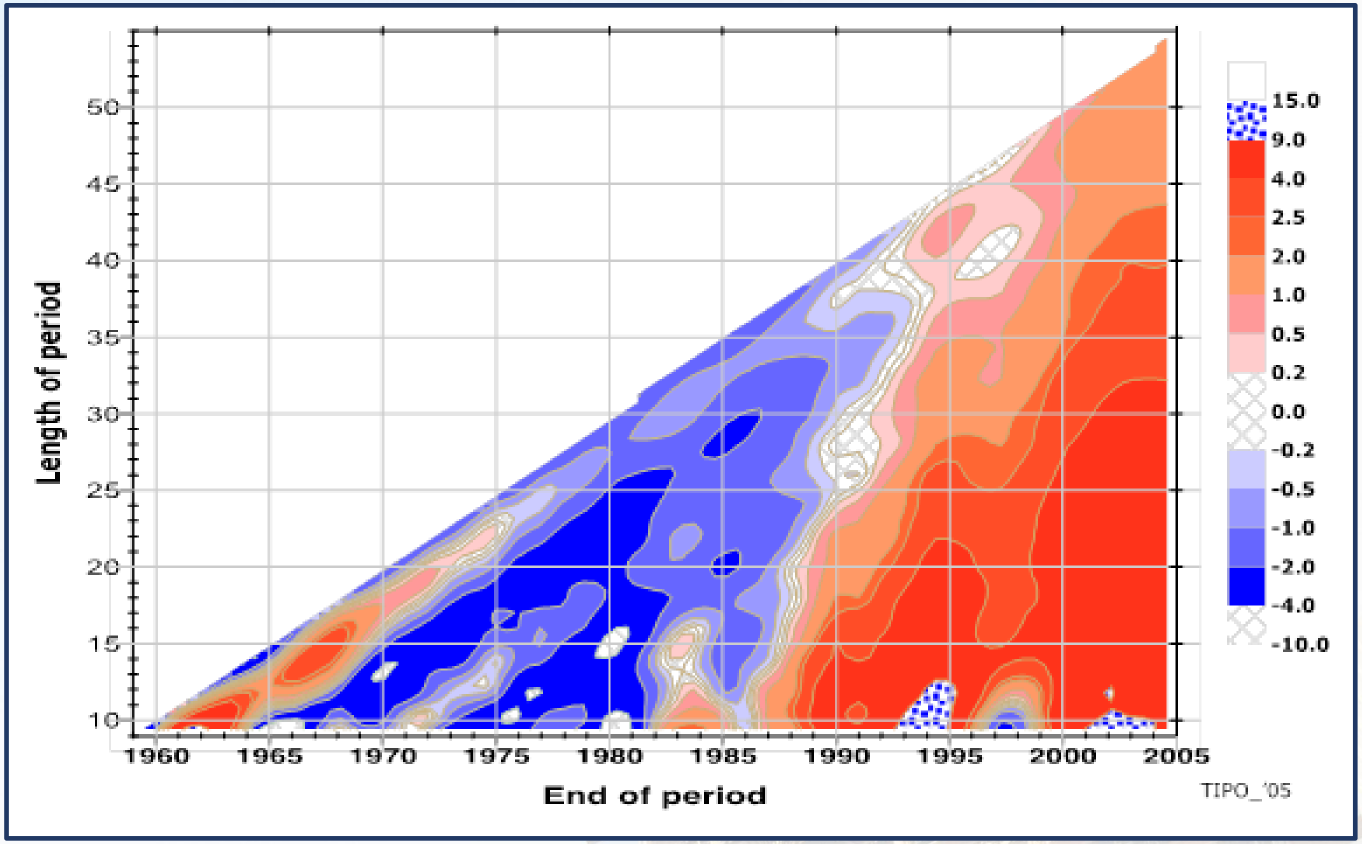




Weather data: Ćuprija, Republic of Serbia		
Heating and cooling design load weather data		
Latitude	43,93°N	
Longitude	21,38°E	
Height	125 m asl	
Climate Design Data:	2013 ASHRAE Handbook	
Design data	Cooling	Heating
Design dry bulb temperature:	32,5°C	-11,6°C
Mean coincident wind speed:	2 m/s	0.5 m/s

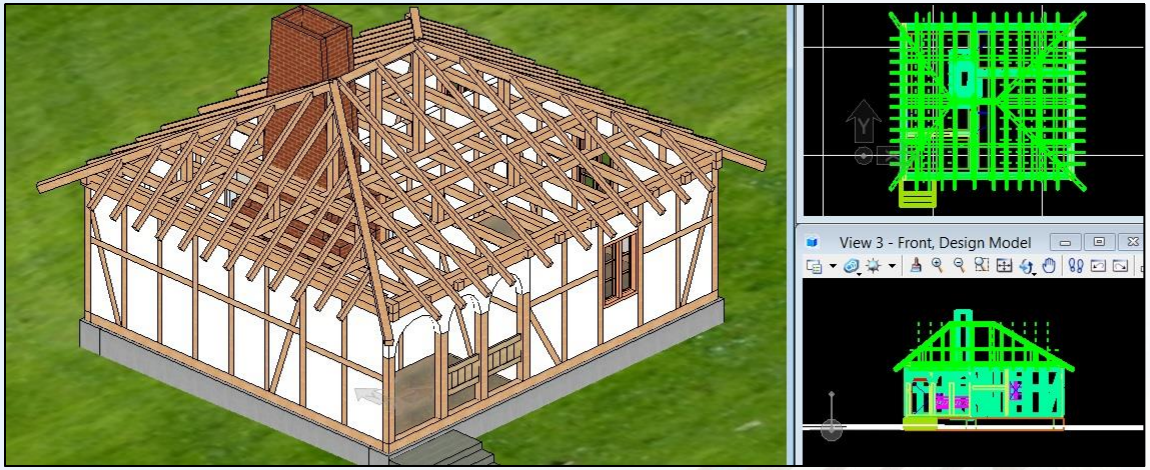
Local Climate Change Relevance for Climate Resilience

Annual air temperature in Serbia has increased intensively, more than 4.54°C /100 years. Shorter periods have higher positive values, which practically mean that the warming has been intensified annually in recent years

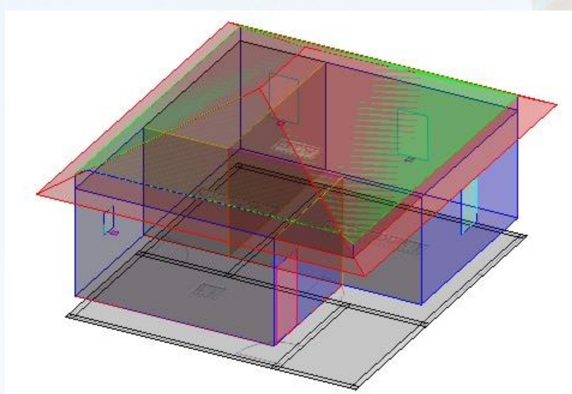


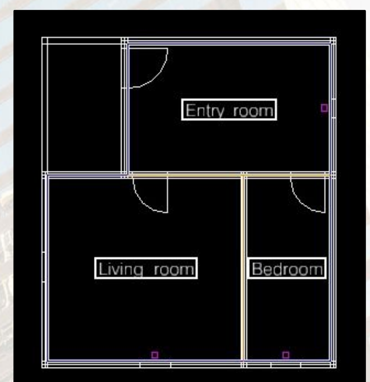
House Model

Bentley AECOsim Building Designer house model with displayed roof and wall structure



Bentley AECOsim Energy Simulator house model

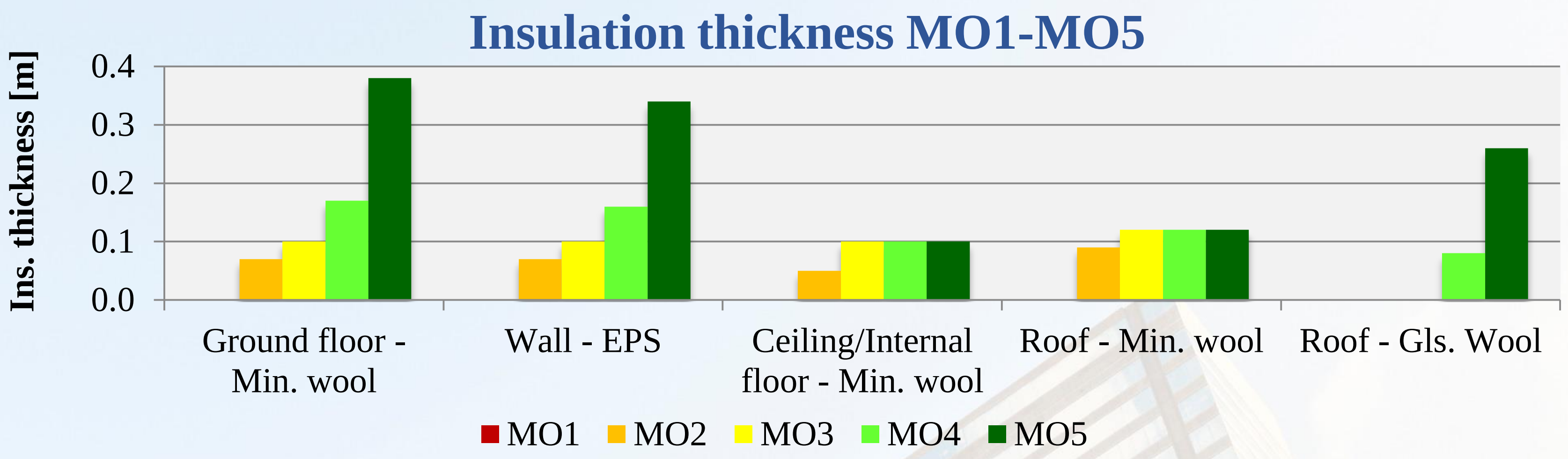


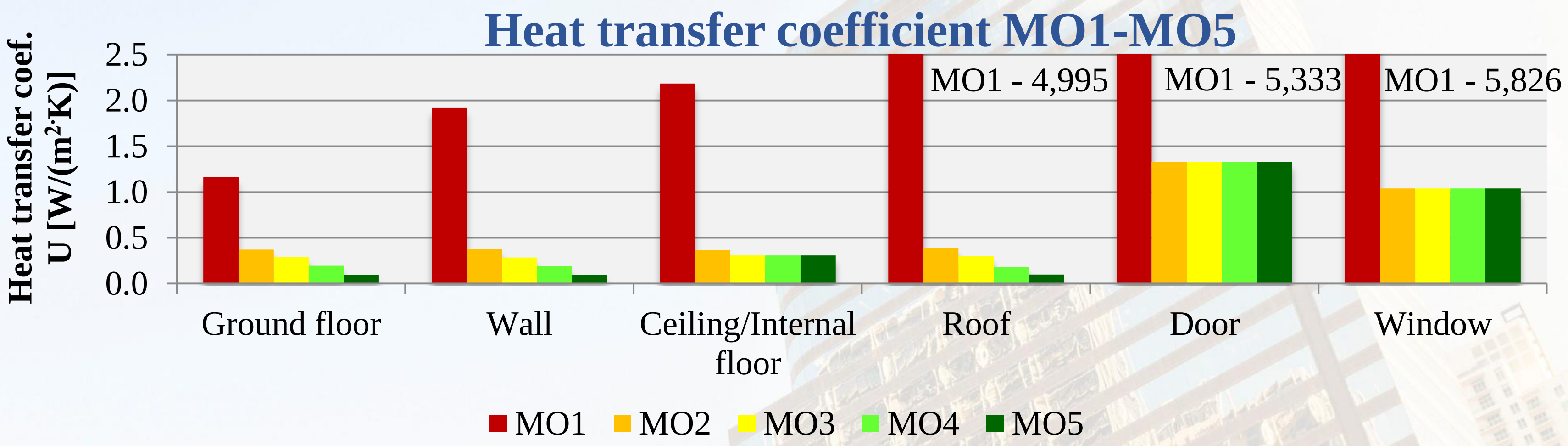


3D house model

Ground floor – top view

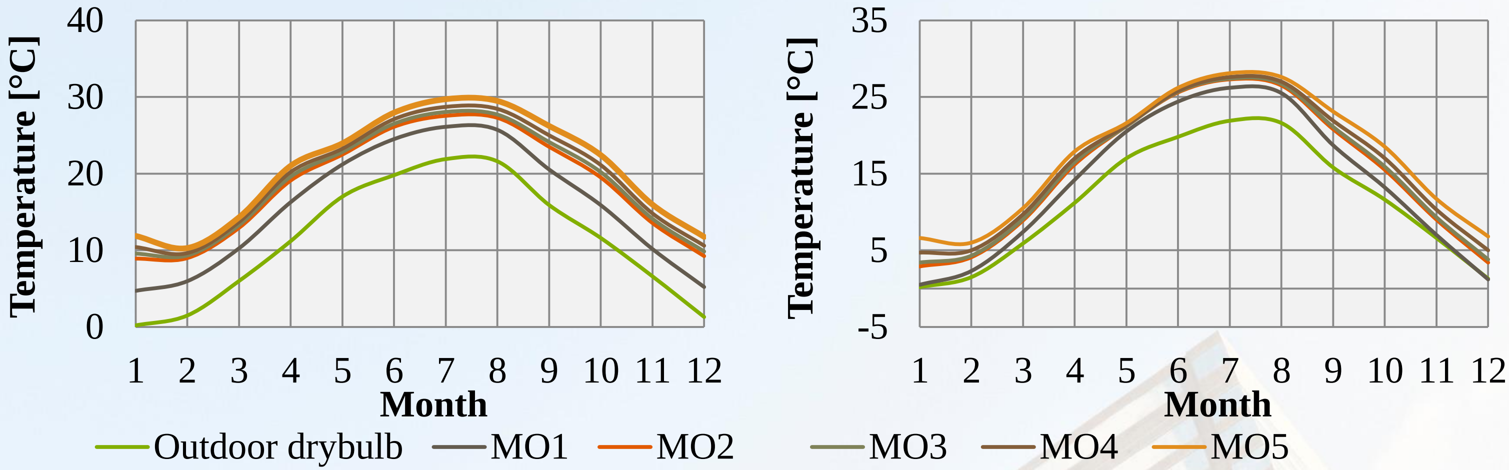
Insulation layers thickness and heat transfer coefficient values

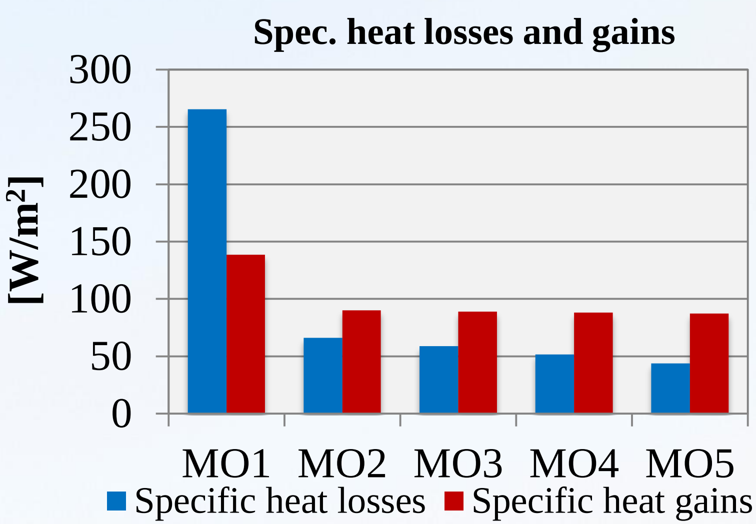


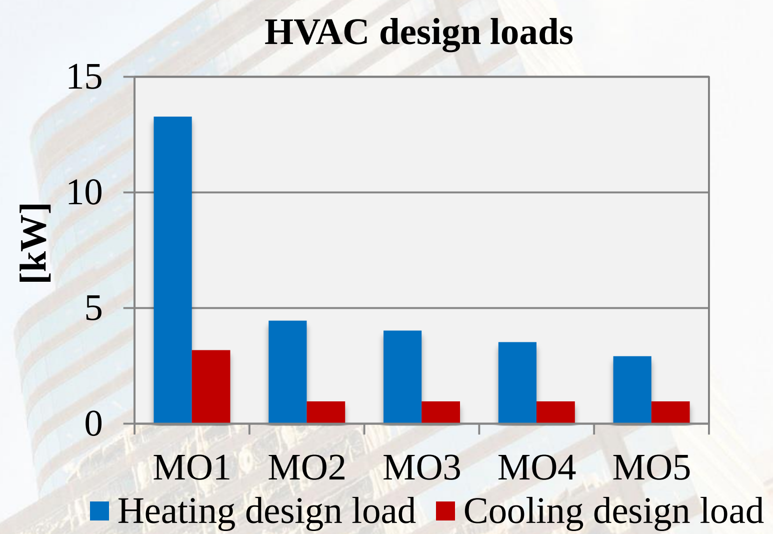


Energy Loads

Free floatng regime - monthly mean air temperature change for ground floor (left) and attic (right)

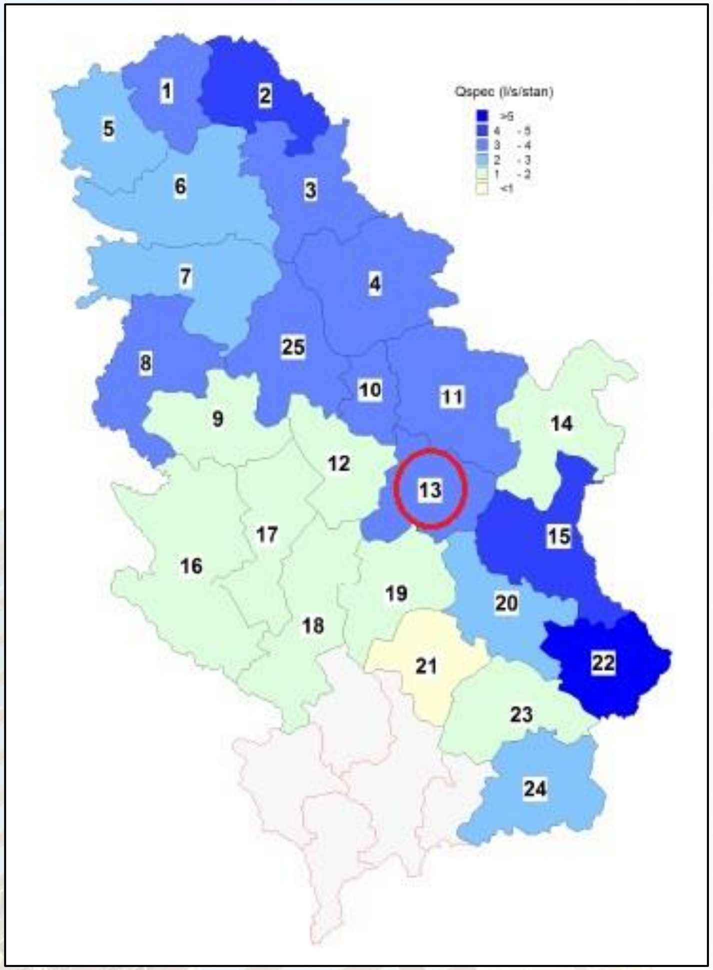






From Energy Mix to Renewable Energy Supply

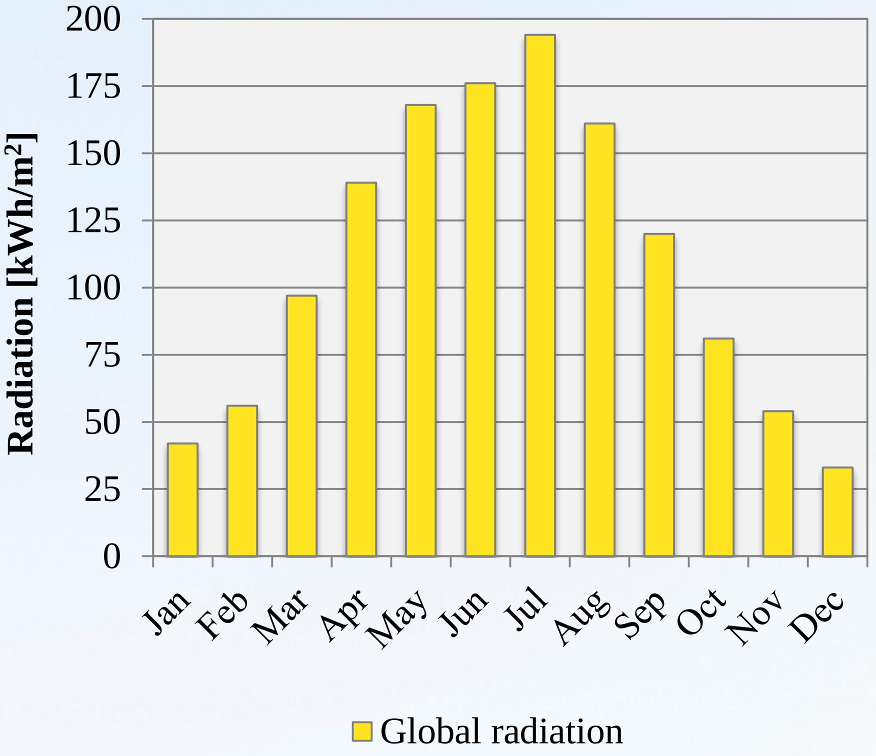
- Locally available <u>biomass forest wastes</u>, <u>groundwater, as well as solar radiation</u> availability at the area on which the house is located, offers reliable prospects for design and construction of sustainable energy supply system.
- Main energy demand of house heating and cooling system can be satisfied combining groundwater heat pump use and electricity production by the building integrated photovoltaic (PV) panels & biomass utilization,.



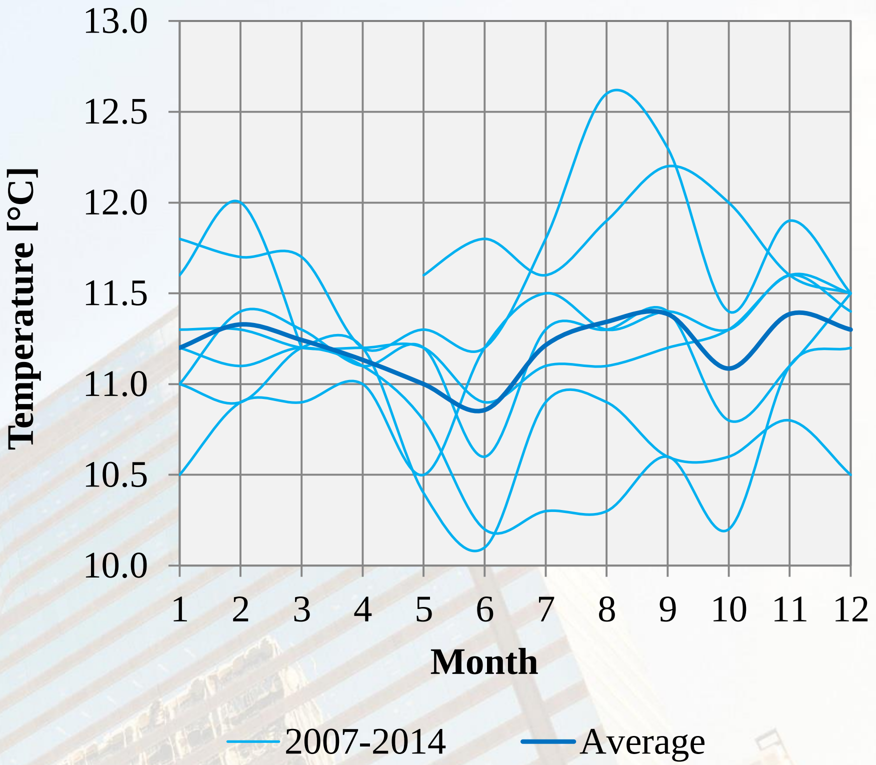
Underground water Availability in Serbia

Solar and Geo - Hydrogeological Data

Annual solar radiation profile



Groundwater temp. oscillation profile



Zero Fossil Energy House as Final Result

The value of 4.800 kWh/t of pellet was used for the conversion of annual electric energy consumption for heating to required biomass amount.

Annual Biomass needs for heating

Biomass needs for heating					
Model	MO1	MO2	MO3	MO4	MO5
Biomass [kg/year]	2936	648	552	460	358

PV modules characteristics

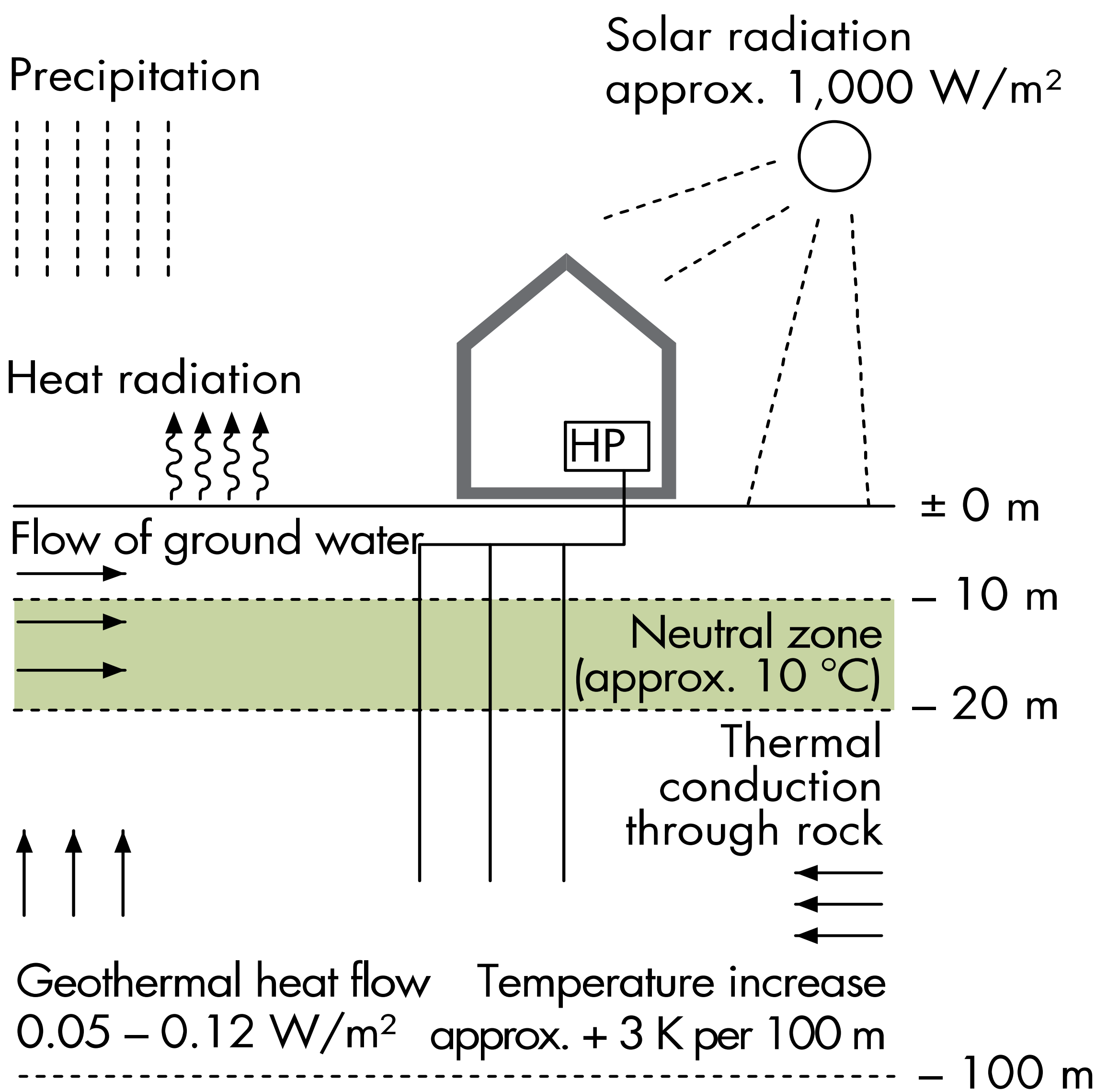
STC 250 W P PV Panels Characteristics	
Power output	250 W
Short circuit current	8.65 A
Open circuit voltage	37.85 V
Current at P_{max}	8.3 A
Voltage at P_{max}	30.12 V
Temp. coeff. at SC current	+0.04%/°C
Temp. coeff. at OC voltage	-0.35 mV/°C

Even More EnergyPlus House as Final Result

MO2-MO5 – Total electricity demand and PV electricity production [kWh]					
Month	Demands	PVmin		PVmax	
		[kWh]	[%]	[kWh]	[%]
Jan	219.60	107	48.7	284	129.3
Feb	195.91	146	74.5	391	199.6
Mar	214.35	247	115.2	659	307.4
Apr	204.22	256	125.4	683	334.4
May	216.34	306	141.4	815	376.7
Jun	226.07	309	136.7	824	364.5
Jul	243.87	330	135.3	879	360.4
Aug	245.95	314	127.7	838	340.7
Sep	211.94	250	118.0	665	313.8
Oct	214.19	211	98.5	563	262.9
Nov	211.52	134	63.4	357	168.8
Dec	221.11	86	38.9	229	103.6
Total	2625.06	2696.00		7187.00	
PV panels power production					
Number of modules		9		24	
Installed PV power [kW]		2.25		6.00	
Total panels area [m^2]		13.14		35.04	

Electricity demands and PV electricity production

Fig. 3: Heat regime in upper layers of ground*



*as per VDI 4640, Sheet 1

VDI 4640

Thermal Use of the Underground

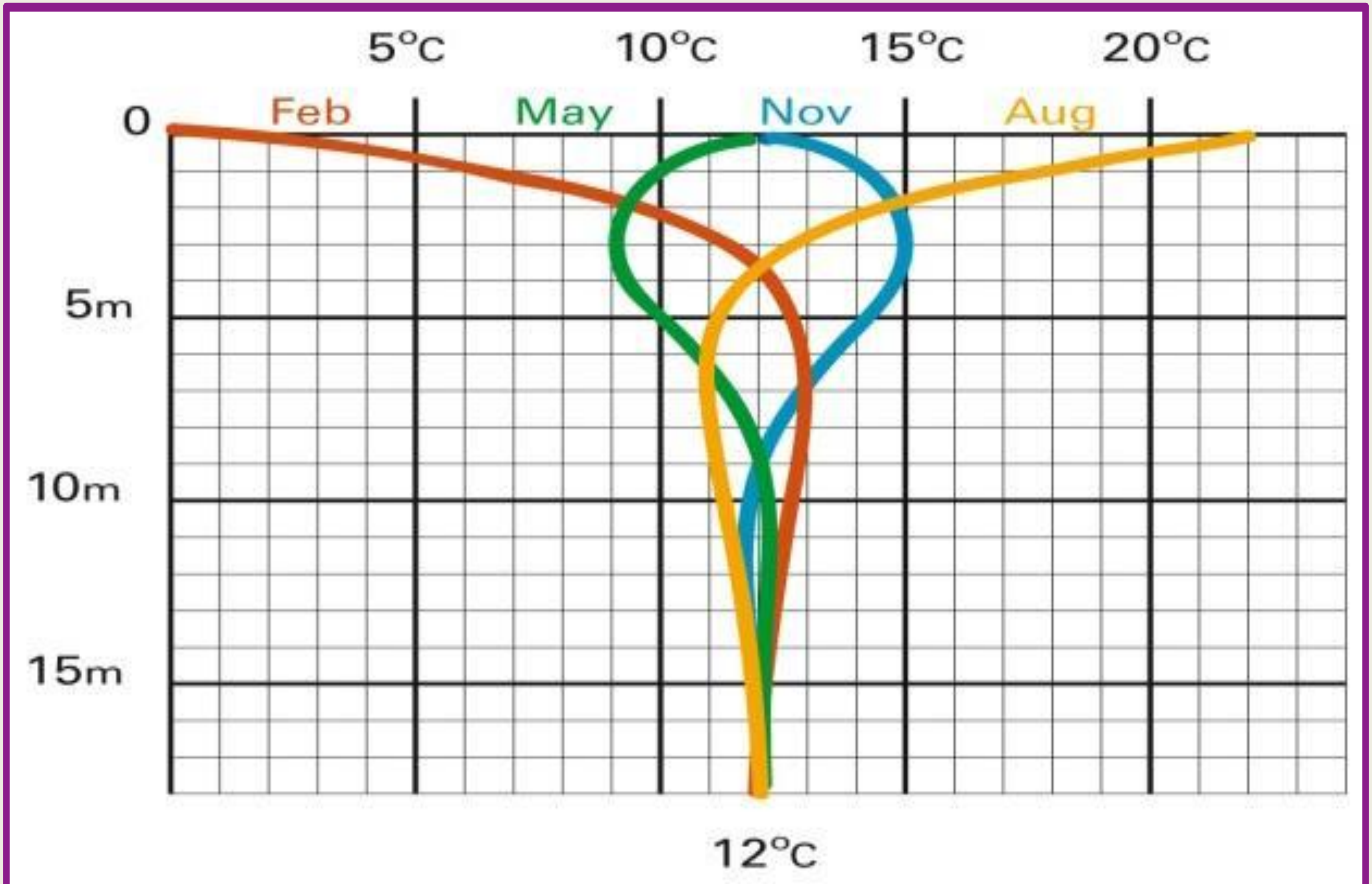
Part 1 - Fundamentals, approvals, environmental aspects

Part 2 - Ground source heat pump systems

Part 3 - Underground thermal energy storage

Part 4 - Direct uses

Average Underground Temperatures



VDI 4640
Blatt 2 / Part 2

Ground Source Heat Pump Systems

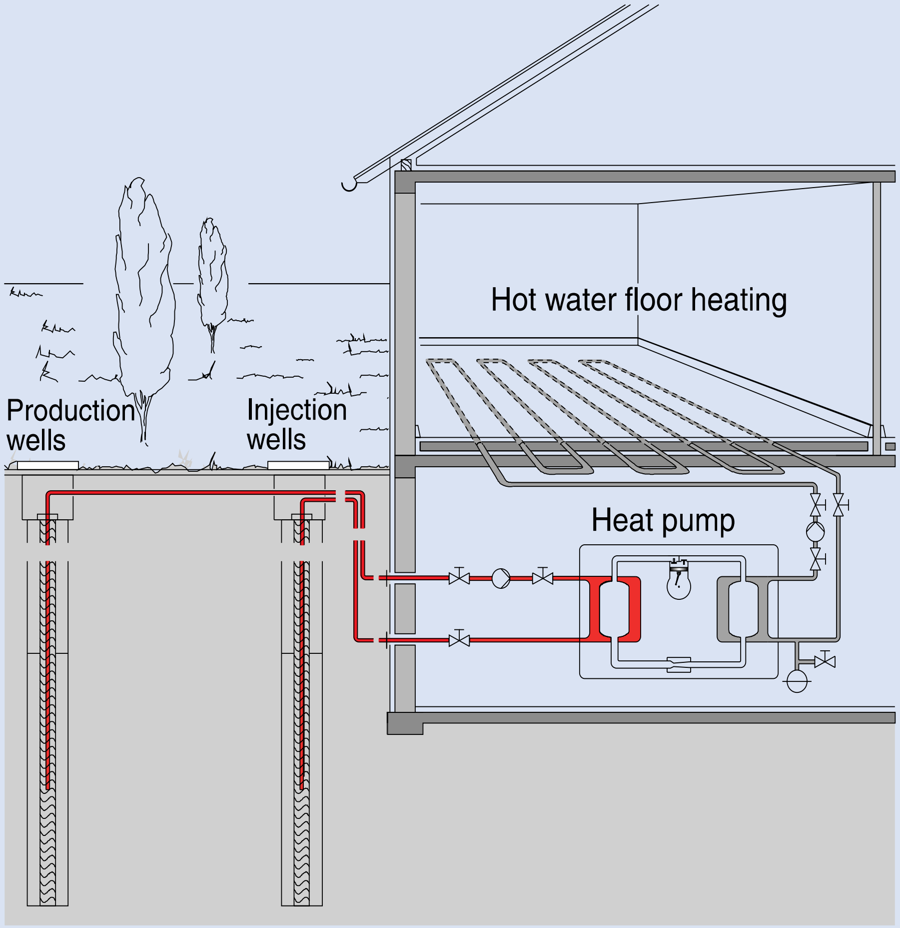


Fig. 1. Schematic of a heat pump with ground water wells

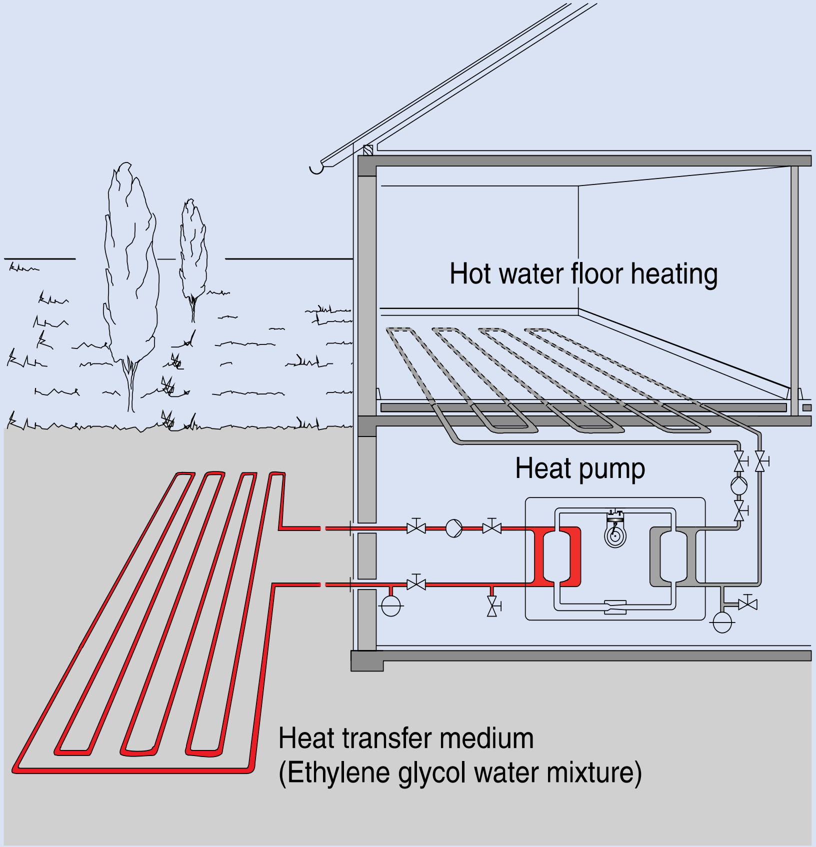


Fig. 3 Schematic of a heat pump with a horizontal ground heat exchanger

VDI 4640
Blatt 2 / Part 2

Ground source Heat Pump Systems

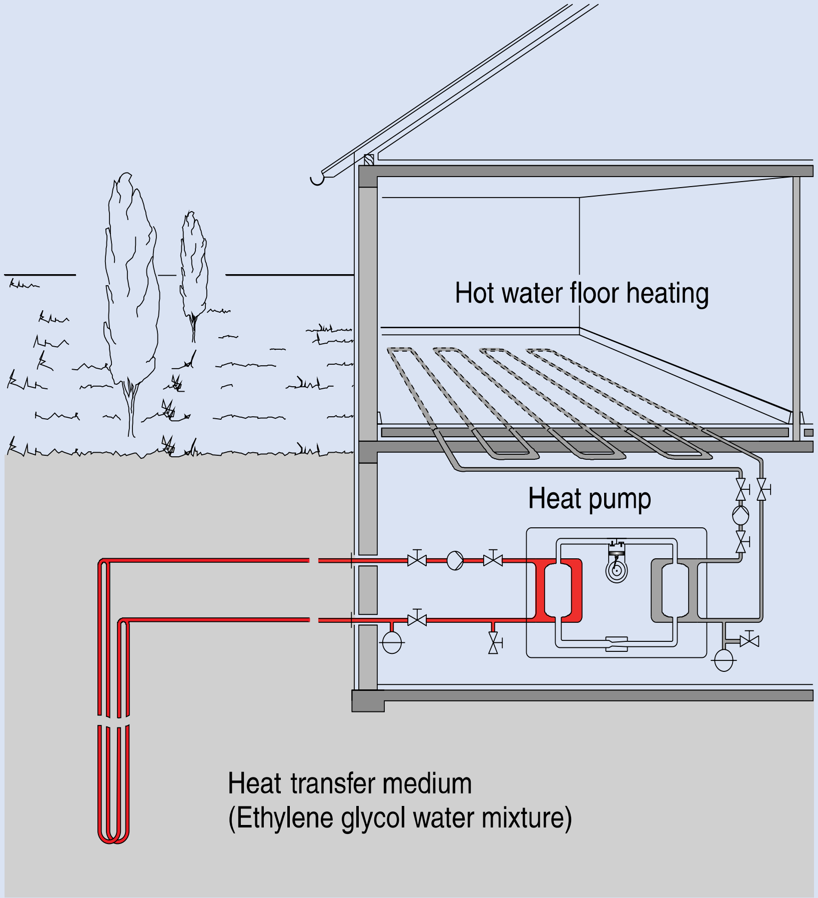


Fig. 4. Schematic of a heat pump with borehole heat exchangers

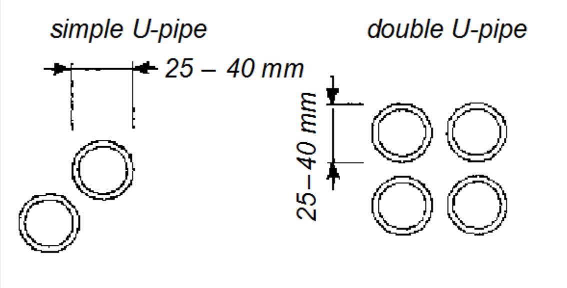
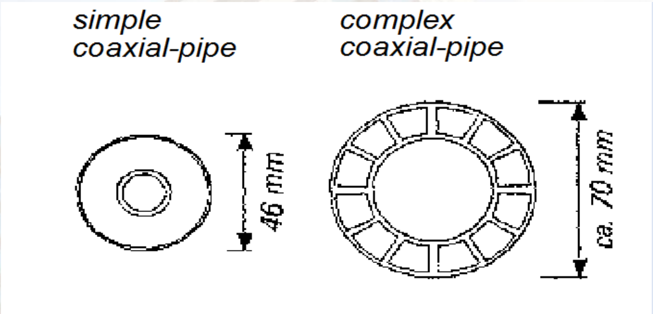


Fig. 6. Different models of borehole heat exchangers in cross-section:



: Dimensioning only typical examples as reference values

Also given Nomogram for Designing borehole heat exchangers

Additional considerations for design of energy piles

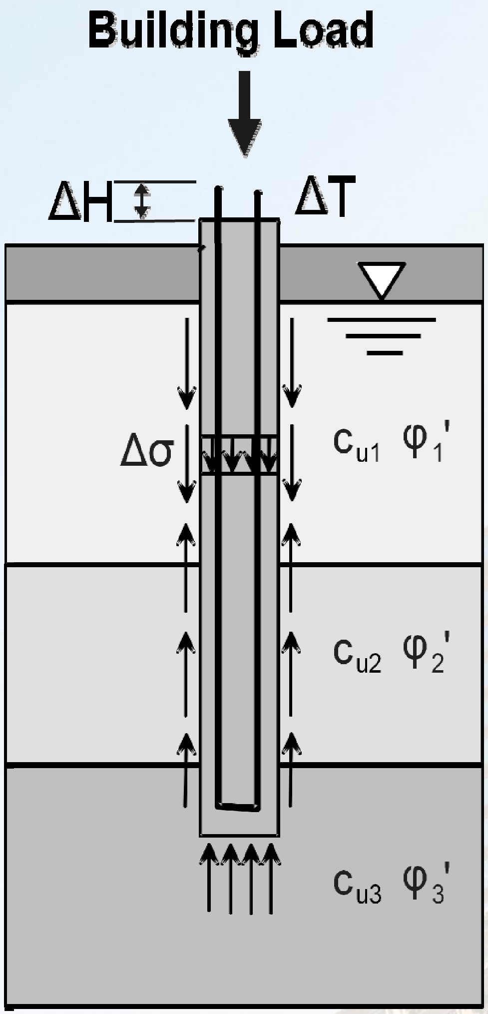
Normal pile design considerations

ULS

- Stratigraphy and soil properties
- Shear / radial stresses
- End bearing

SLS

- Pile settlement
- Differential settlement
- Concrete stress
- Negative skin friction



Additional thermal pile design considerations

ULS (Appendix D)

- Soil strength properties considering heating and cooling effects

SLS (Appendix E)

- Axial and radial pile expansion / contraction / fixity
- Thermally induced axial stresses
- Cyclic effects of thermal loading
- Temperature at soil-pile interface including daily / seasonal variations

ultimate limit state (ULS) / serviceability limit state (SLS)

Measured Energy Pile System Performance

The foundation piles contribute by being used as energy piles: about 300 piles have been equipped with 5 U-pipe fixed on the metallic reinforcement to use them as a heat exchanger with the ground.

- Measurements of the energy pile system begun in October 2004 for a 2 years period.
- Peak power loads are met with district heating used in complement to the heat pump.
- 85% of the annual heating demand, which was established to 2,720 MWh/y, should be covered by the heat pump.

Large Scale RES Use Needs Energy Storage

The main problem of the RES (renewable energy sources) use is their intermittency, variable intensity and quality - features which are not matching the way the traditional electricity grid operates.

- ❑ To keep balance between the supply and demand - crucial for stable distribution system, the only real option is to store the energy when it's produced, and send it to the grid when it's needed.
- ❑ Hence, it is necessary to find innovative ways of large-scale storage systems and large storage volumes to solve problem of interruptible availability and variable intensity quality of most types of RES.
- ❑ Worldwide, many abandoned mines (of coal or minerals) offer large storage volumes almost ready-made to be used directly for energy storage. Related technologies and a few case studies are reviewed.

NREL Report/TP-6A2-47187 January 2010

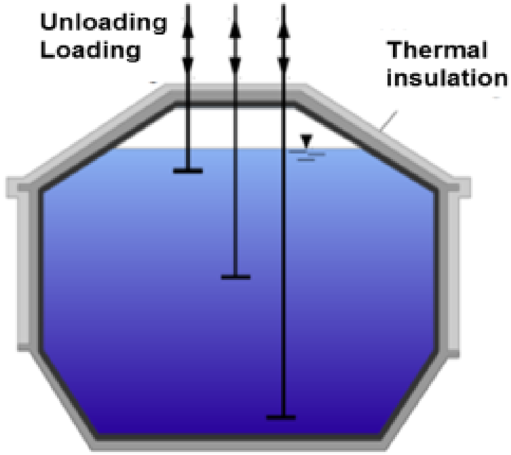
The Role of Energy Storage with RES Electricity Generation

Because their intermittency and variability there is need for the deployment of energy storage as an essential component of energy systems that should use at large scale RES.

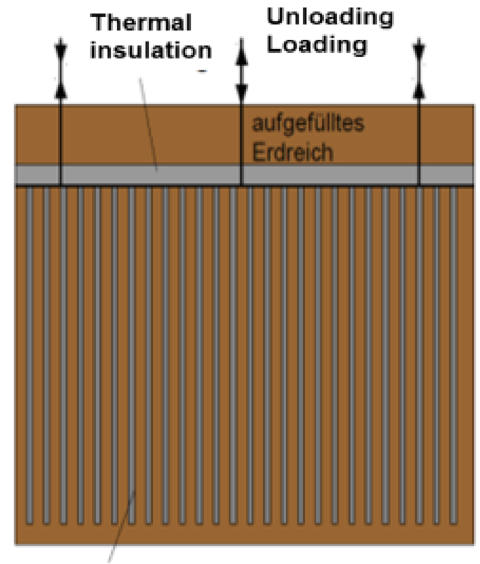
An approach is to be found that can confirm maintenance of the required system reliability, necessary technologies and changes in operational routines, as well as the cost-competitiveness, benefits of the potential technologies enabling energy storage in the electricity grid addressing especially effects of large-scale deployment of wind and solar energy:

- **High-energy batteries**
- **Pumped Hydro Storage (PHS)**
- **Compressed Air Energy Storage (CAES)** and
- **Thermal Energy Storage**.

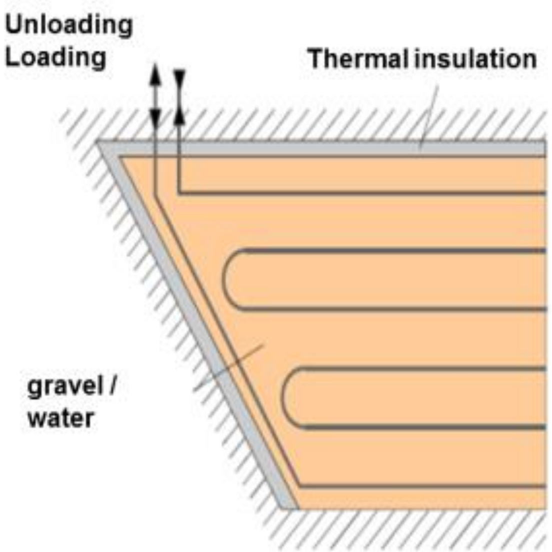
Underground TES Concepts



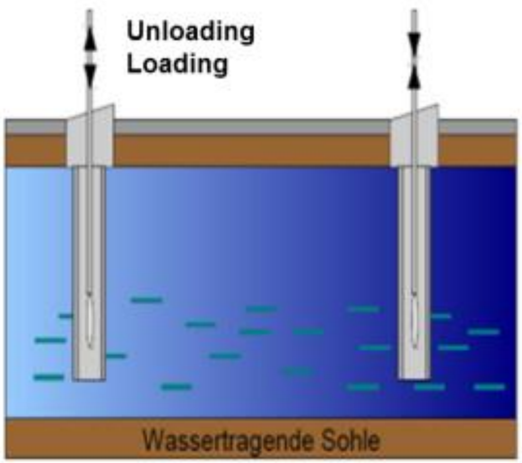
Concrete pit and
hot water store



borehole heat exchanger stores



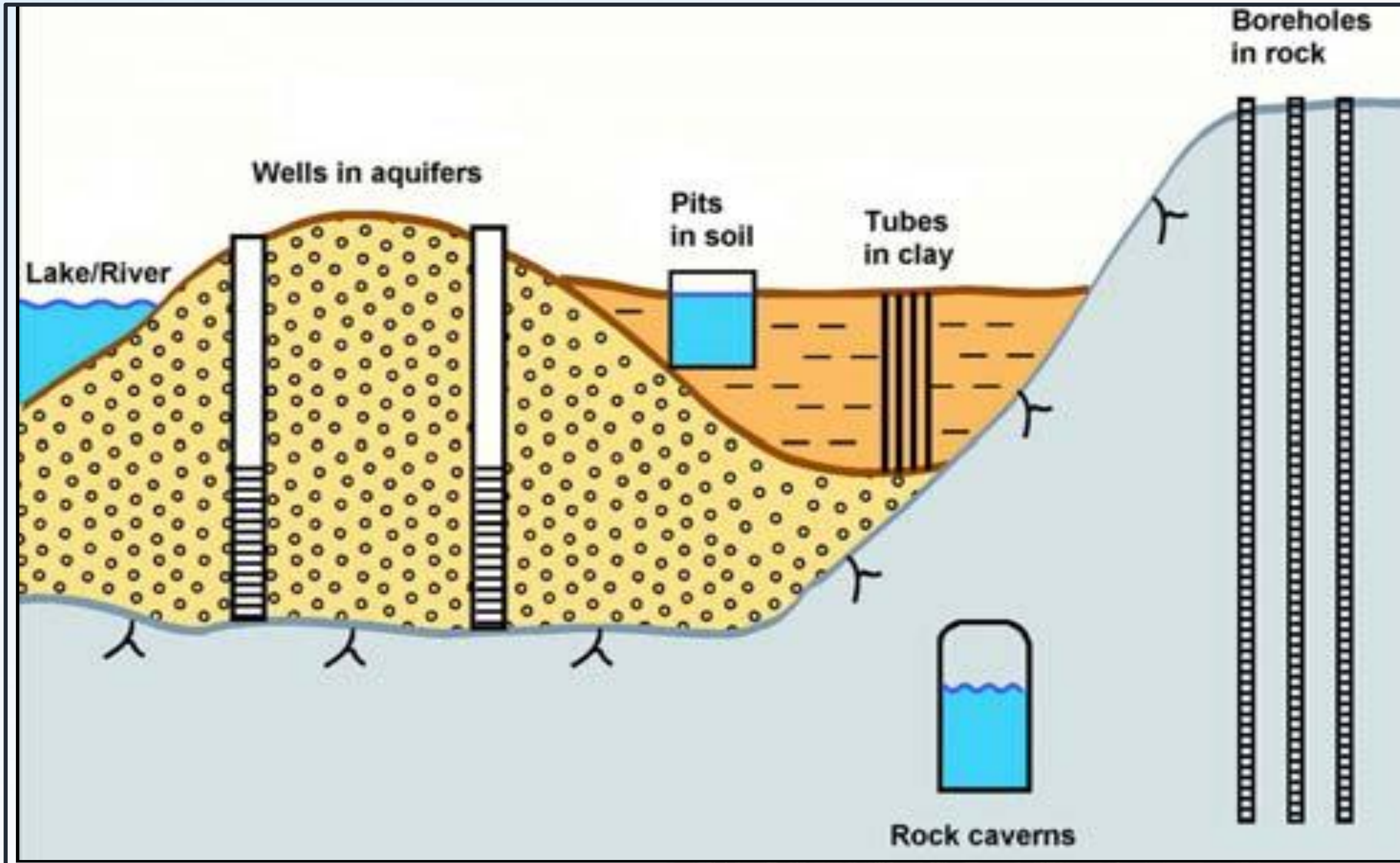
gravel / water stores



Aquifer stores

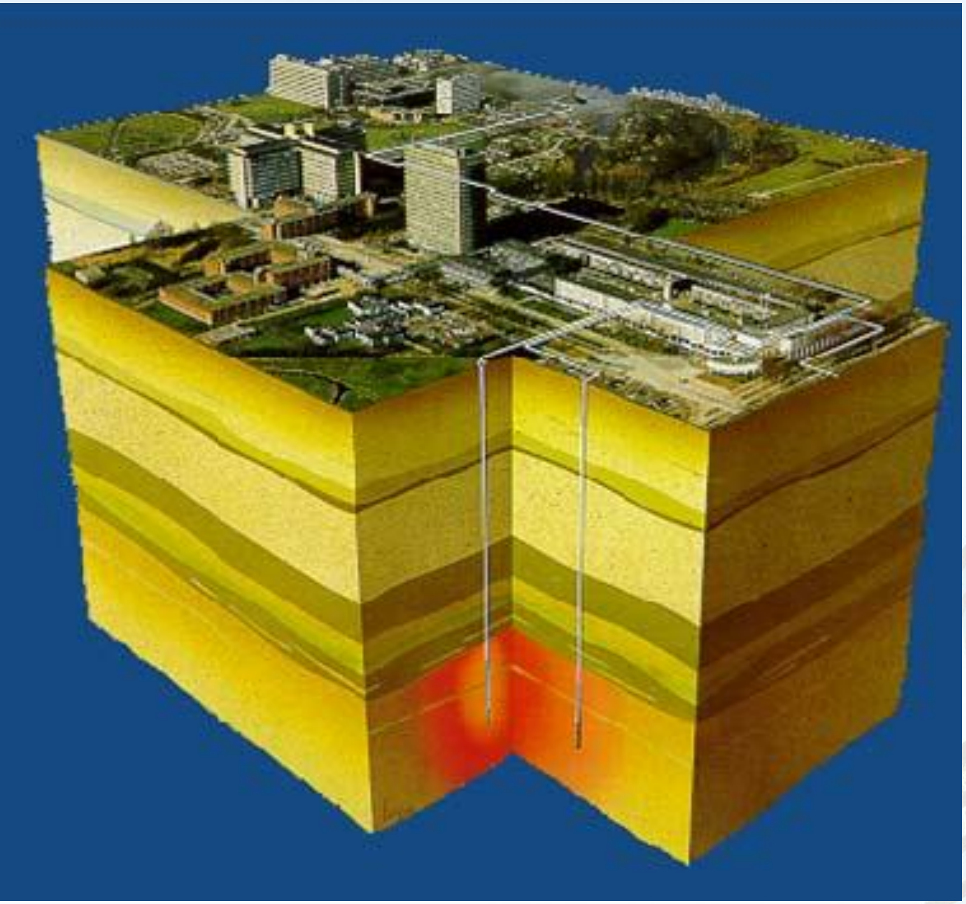
Underground Thermal Energy Storage (UTES)

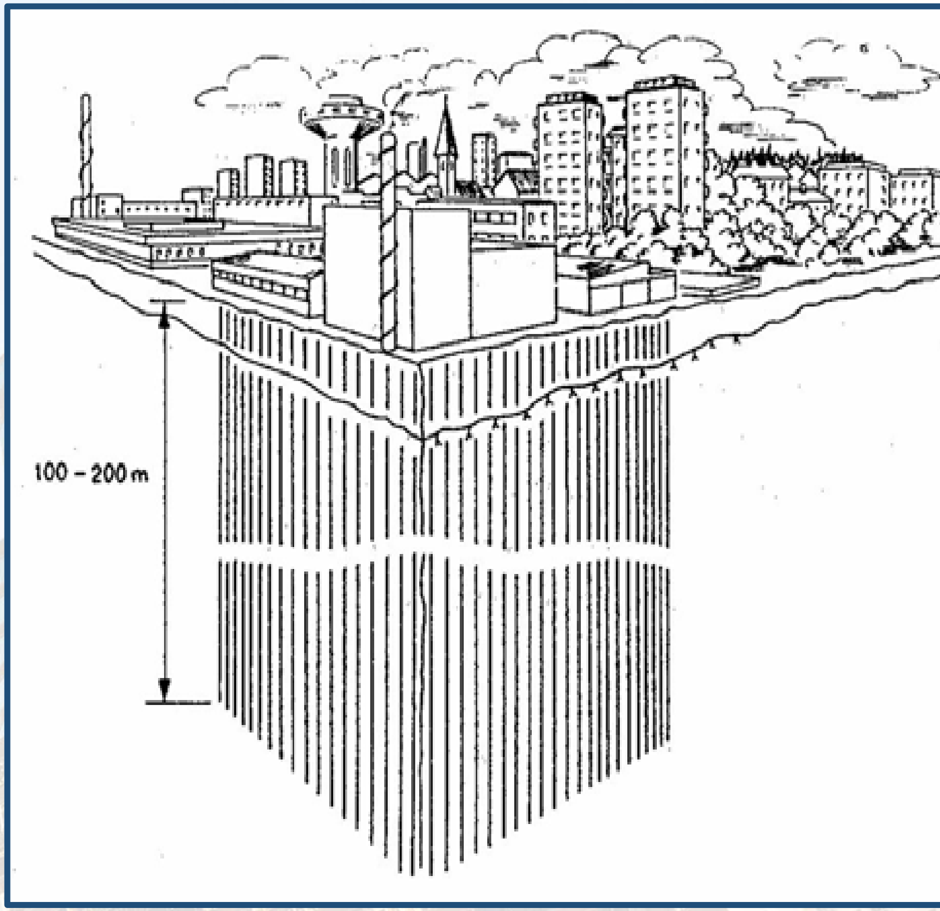
The UTES includes ATES, BTES and CTES i.e. Thermal energy storage in Aquifers, Boreholes, and Caverns.



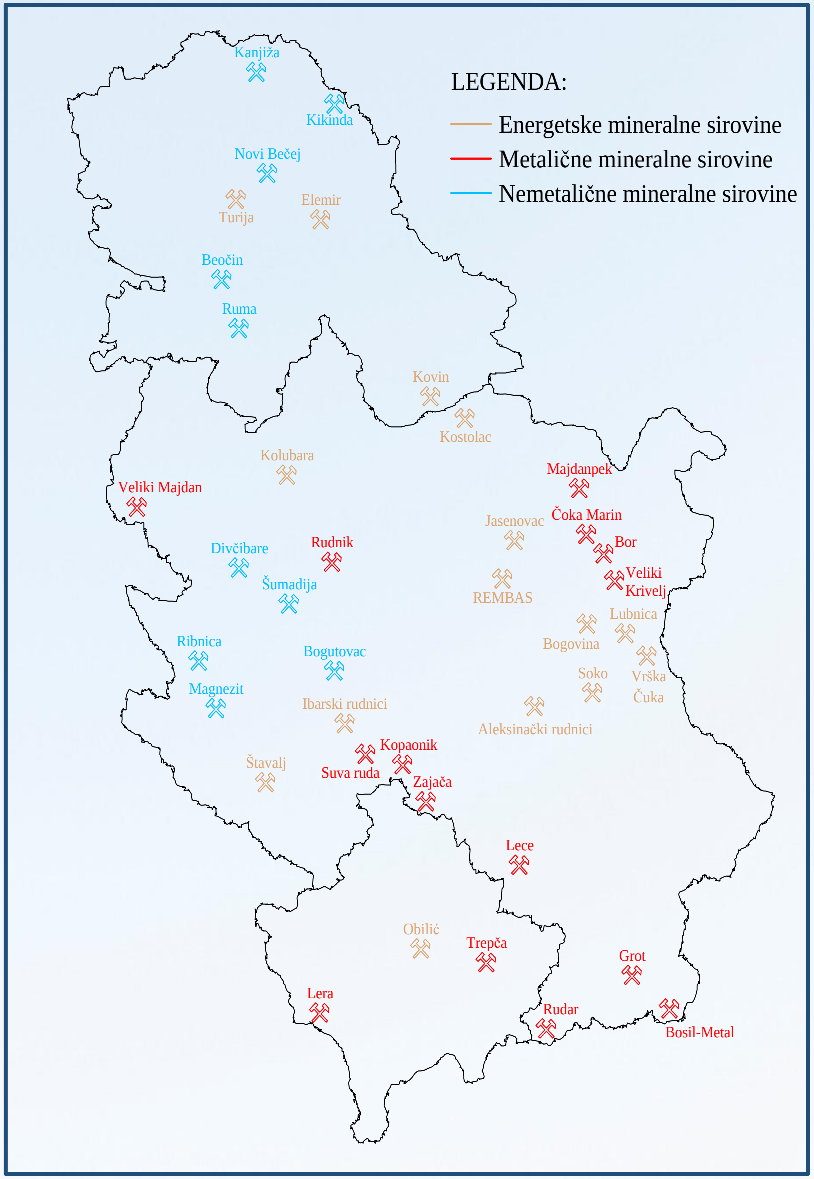
ATES and BTES Exampples

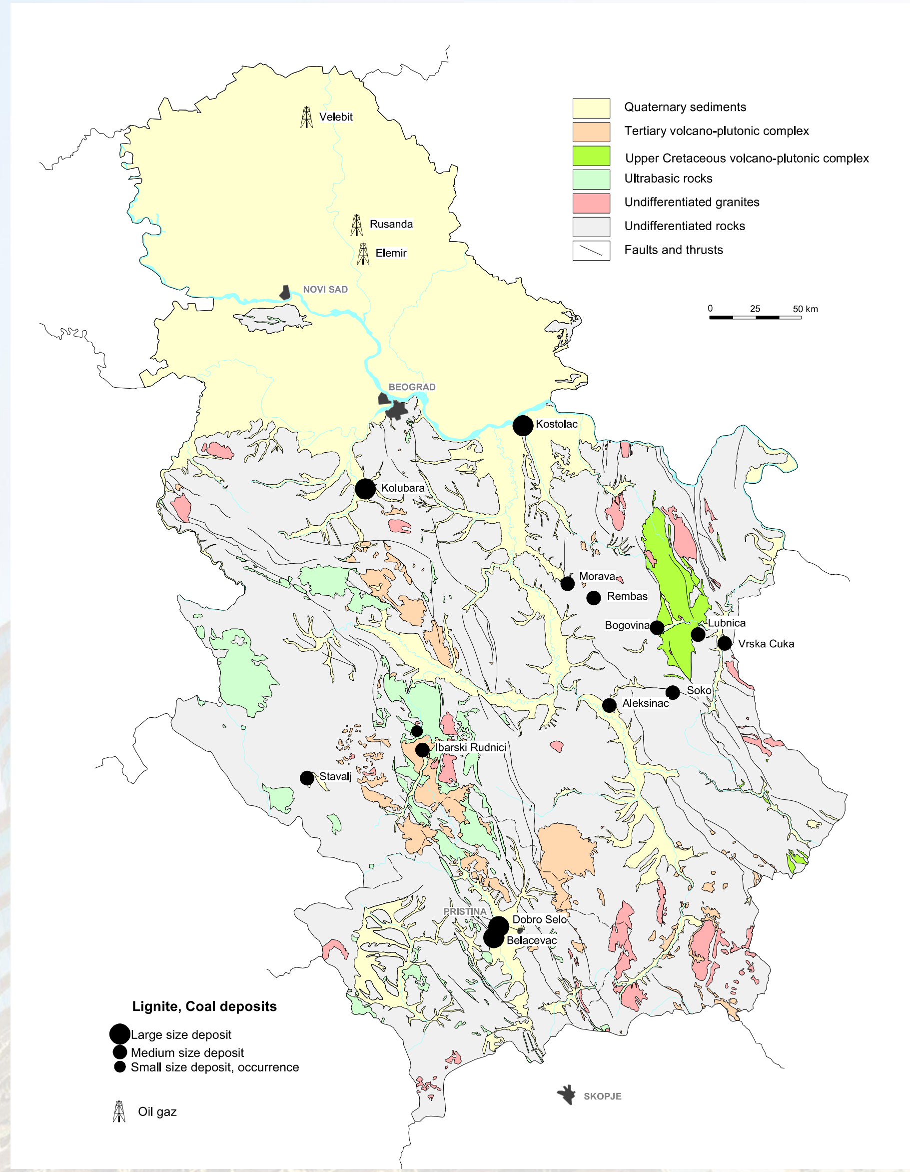
Aquifer TES in Utrecht, Netherlands (left) and Large scale Borehole TES system on the top of the storage can be used as parking lots, parks, and even for constructions (right)





Energy-mineral Deposits in Serbia

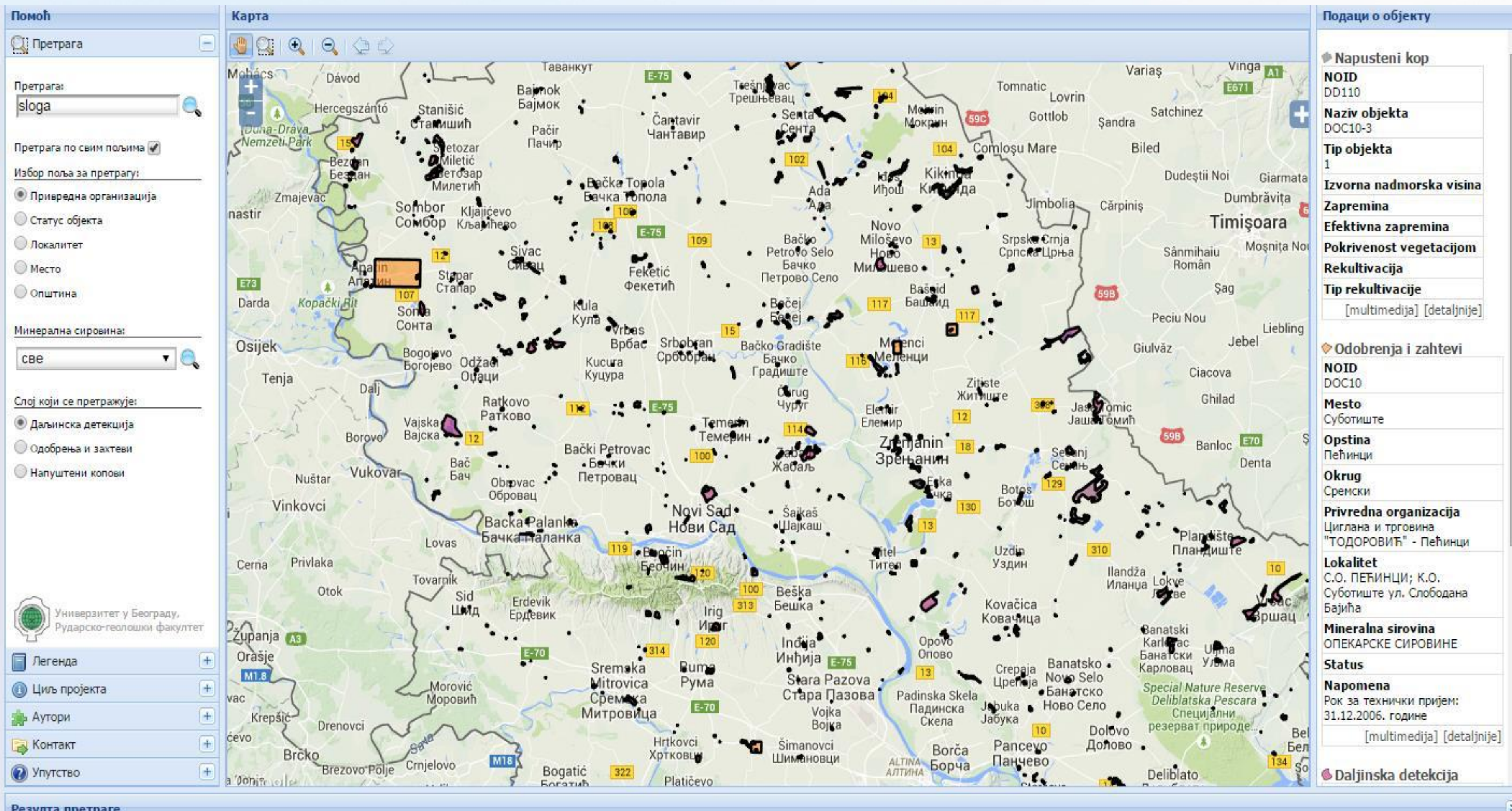




Mines in Repubic of Serbia

WebGIS app. of the Cadastre of abandoned mines of APV

Can have one of the following Google Maps: Physical, Streets, Hybrid or Satellite, depending on user choice: polygons singled with remote sensing and polygons resulting from the analysis of exploitation authorizations, requests for re-cultivation and field visits.



Closing Mines and Ecological Rehabilitation Needs

Closing mines in Romania (mining dating back 100 years B.C.) is focusing mainly exhausted mines of ores.

On Romanian law & special program more than 450 mines was planned to be closed in Romania over 10 years, with a financial provision of approximately US $400 million.

Senjski Mine ECO Museum & Industrial Heritage

Old coal mines can heat our homes again!

Old Cole Mines Can Be Part of Green Energy Future

- Trying to find a way to make a turn from the current one-way irreversibility to sustainability, in addition to the uninterrupted R&D aimed to advance RES (Renewable Energy Sources) technologies it is necessary to find innovative ways of:
  - universal schemes, quantities, indicators and criteria relevant for the sustainable Earth resources utilization
  - environment protection and already damaged environment recovery and rehabilitation.
  - large-scale storage systems and large storage volumes to solve problem of interruptible availability and variable intensity quality of most types of the RES.
- Worldwide, many abandoned mines (of coal or minerals) offer large storage volumes almost ready-made to be used directly for energy storage. Related technologies and a few case studies are reviewed.

THANK YOU
For Your Kind Attention

Questions?

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There is One Way to Reach Sustainable Development – It is a Way via Harmony & Ethics of Sustainability

Or to war for energy sources, water and raw materials and End with the apocalypse