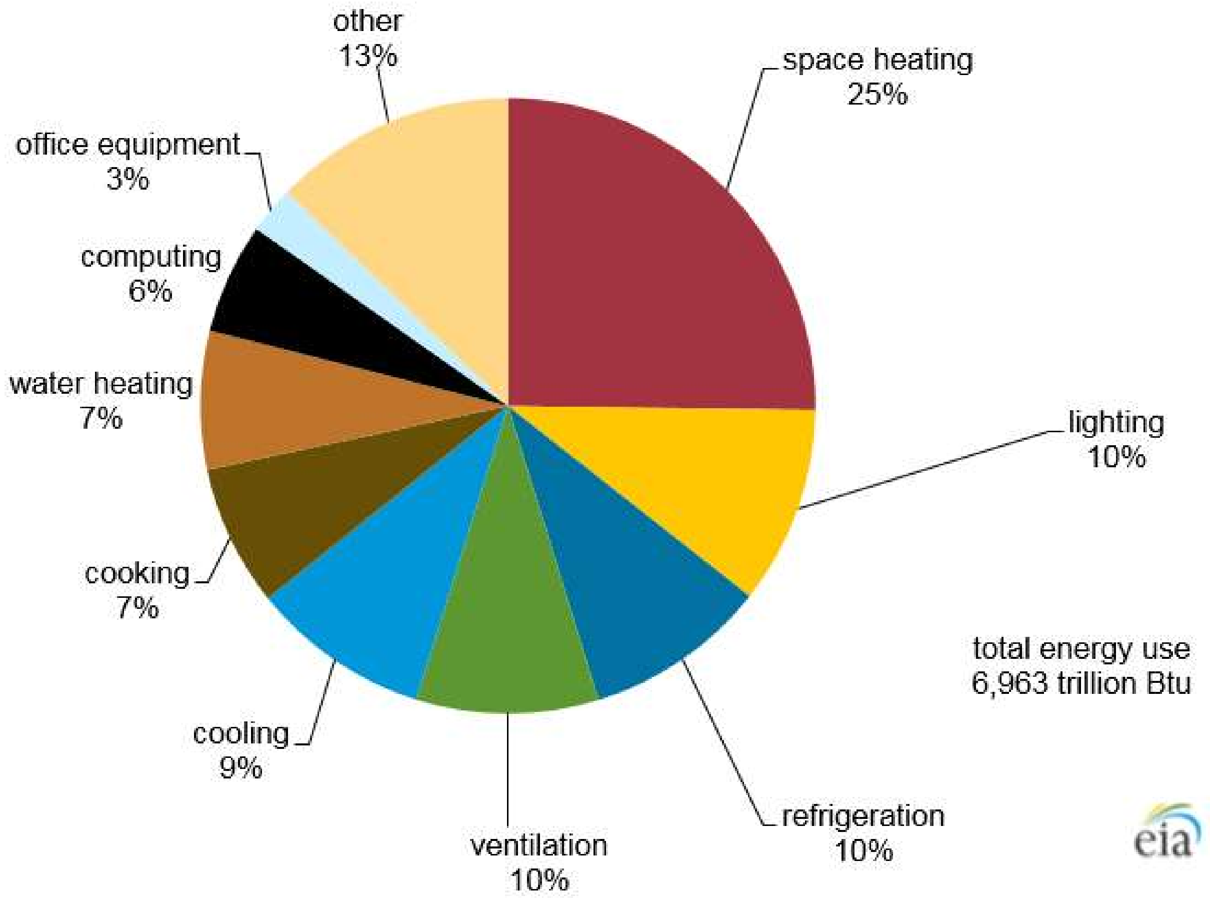
Lecture 3 –
Energy in buildings

Magistère de Physique Fondamentale
Université Paris-Saclay
2019-2020

Energy demands in a building

Figure 5. Space heating demanded the most overall energy use in commercial buildings in 2012, followed by other uses



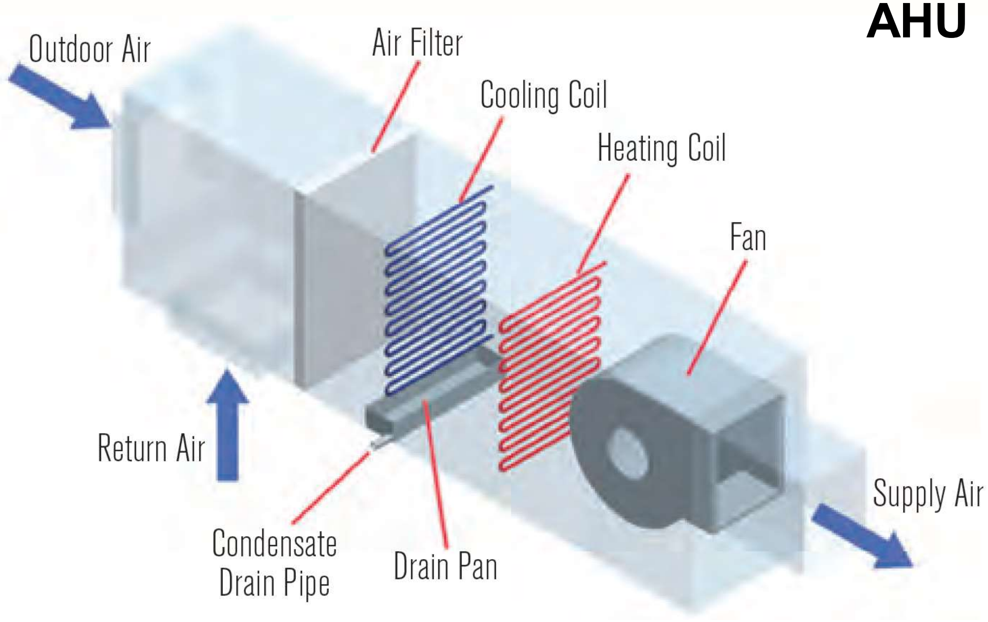
Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey.

Energy demands in a building

Energy demands for :

- Heating
- Cooling
- Hot water
- Air Handling Unit (ventilation)
- Fan Coil Unit
- Dehumidification
- Electrical appliances

AHU



Glawe et al. *ASHRAE J.* Dec 2016

© Wikipedia

Energy demands in a building

Energy demands for :
- Heating
- Cooling
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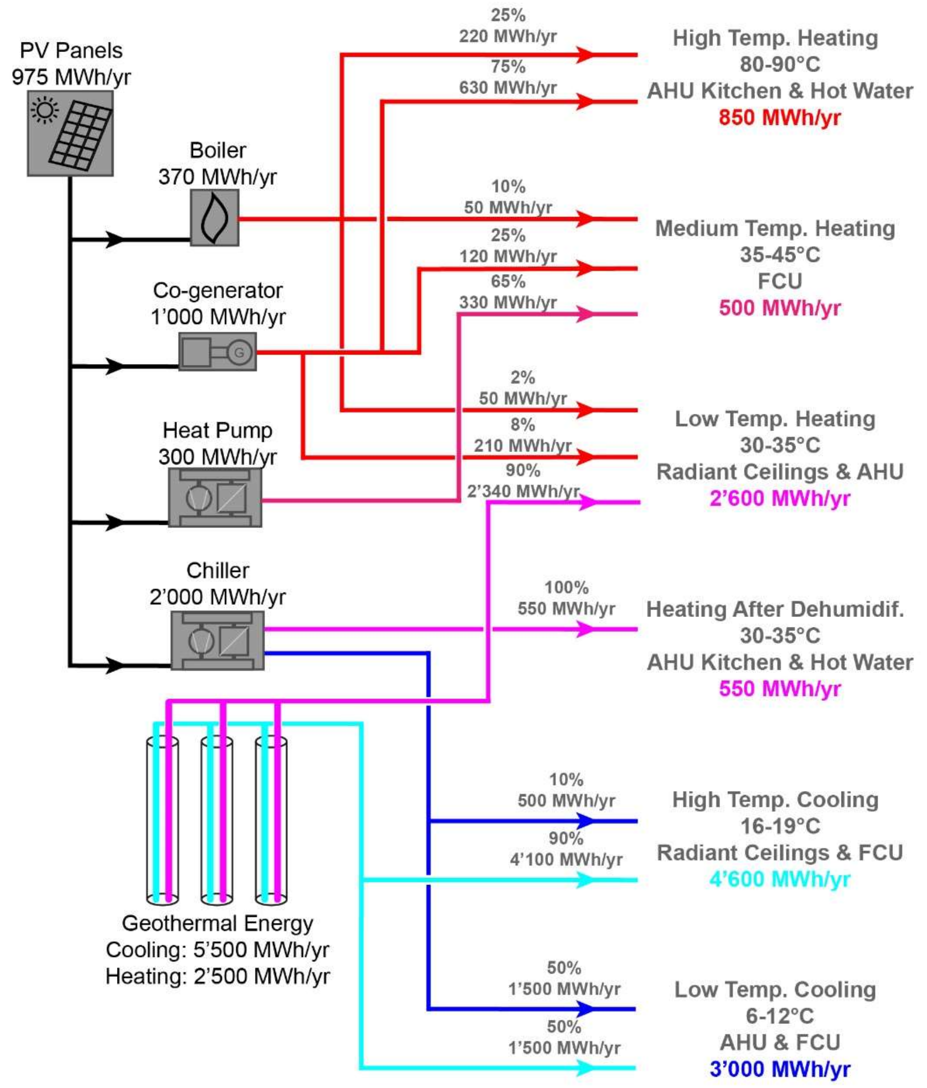
- Fan Coil Unit
- Dehumidification
- Electrical appliances



- Low temperature cooling (6-12°C)
- High temperature cooling (16-19°C)
- High temperature heating (80-90°C)
- Medium temperature heating (35-45°C)
- Low temperature heating (30-35°C)

COP:

$$COP_{heating} = \frac{Q_h}{W}$$

$$COP_{cooling} = \frac{Q_c}{W}$$

C.O.P.	
Boiler	0.9
Heat Pump	5
Co-generator thermal	0.5
Co-generator electrical	0.4
Absorption chiller	0.6
Chiller	7
Cooling Towers	12
Geothermal	20

1. GEOTHERMAL ENERGY

1. Underground buildings
2. Thermal labyrinths / Canadian wells
3. Geothermal energy harvesting

1.1. Underground buildings

Guyaju

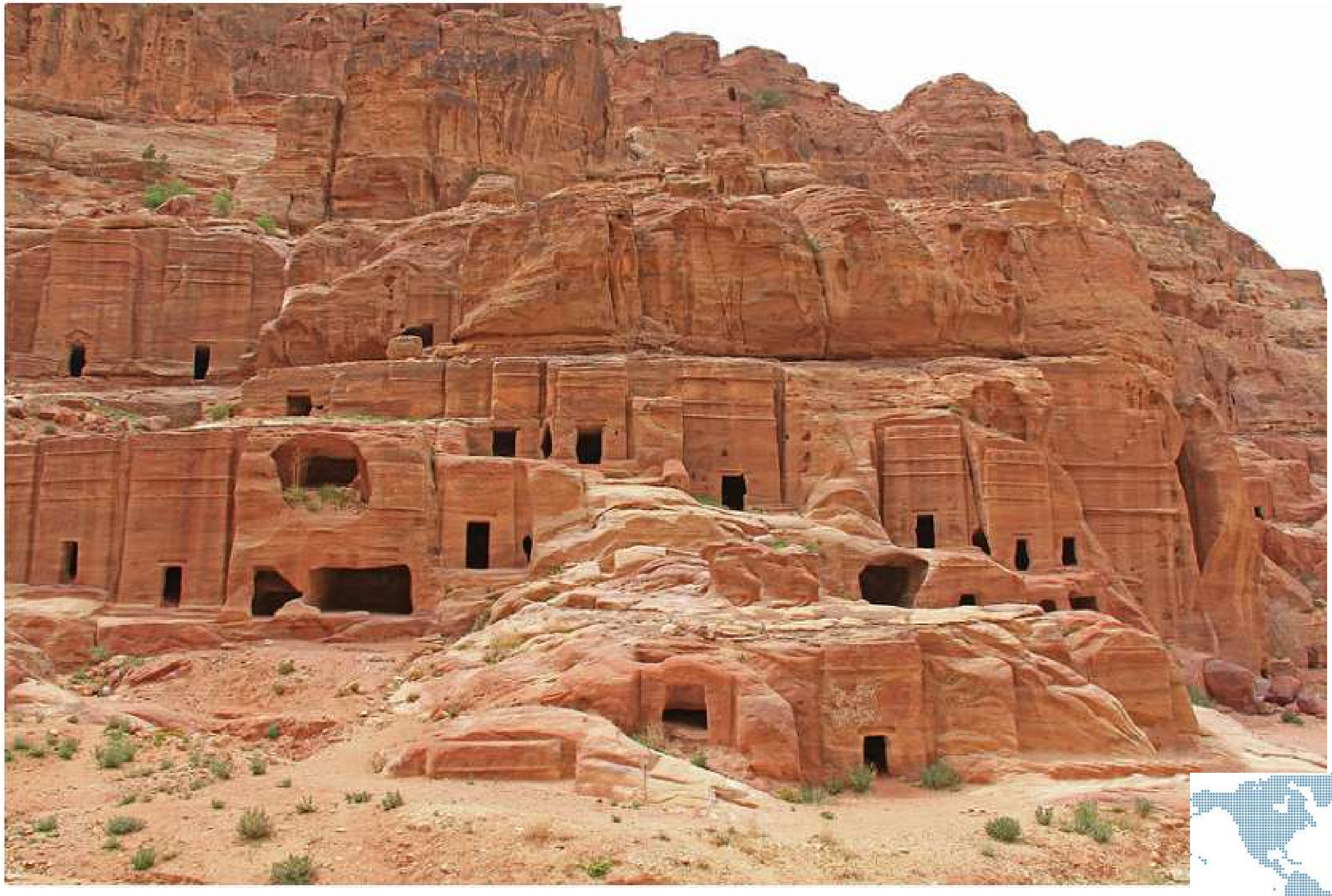
1.1. Underground buildings

Matmata

© travels1z.blogspot.com

1.1. Underground buildings

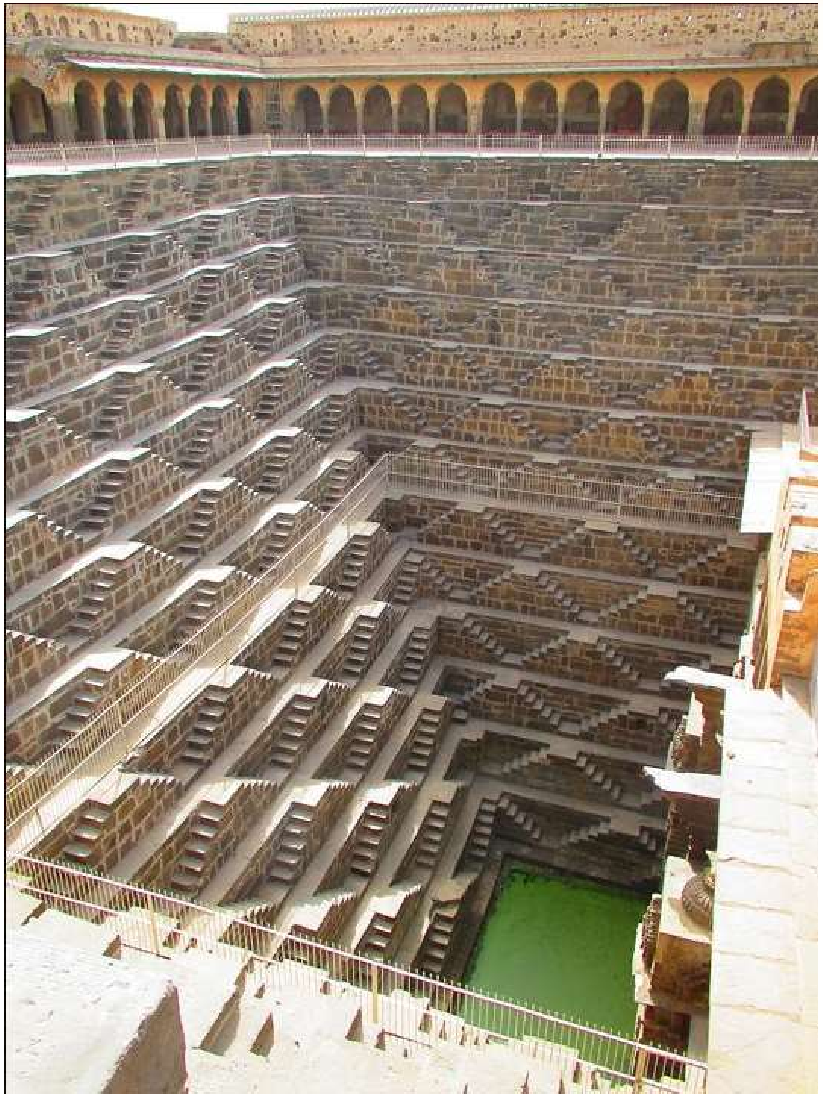
Petra



1.1. Underground buildings

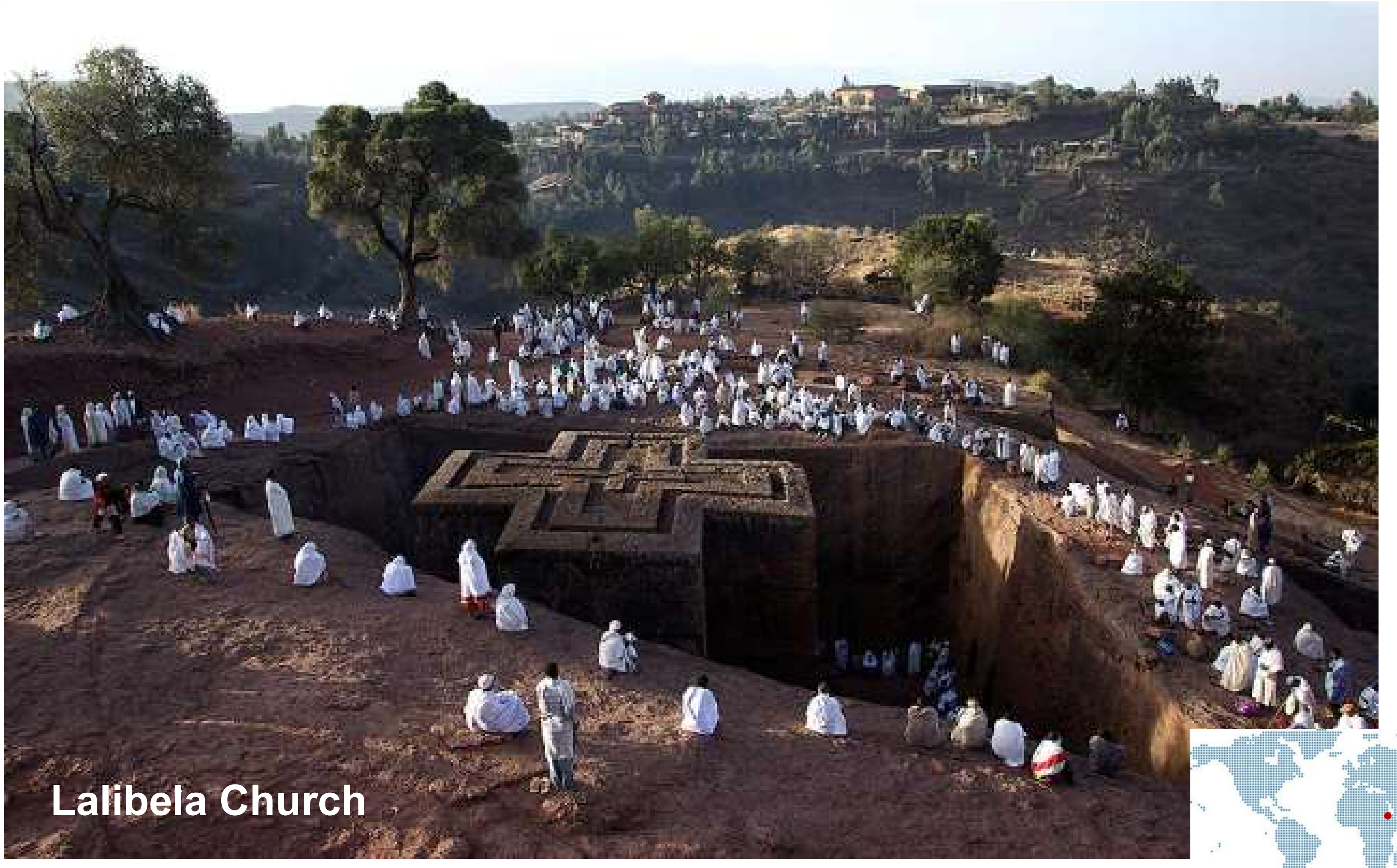
Loess Plateau

1.1. Underground buildings



Chand Baori

1.1. Underground buildings



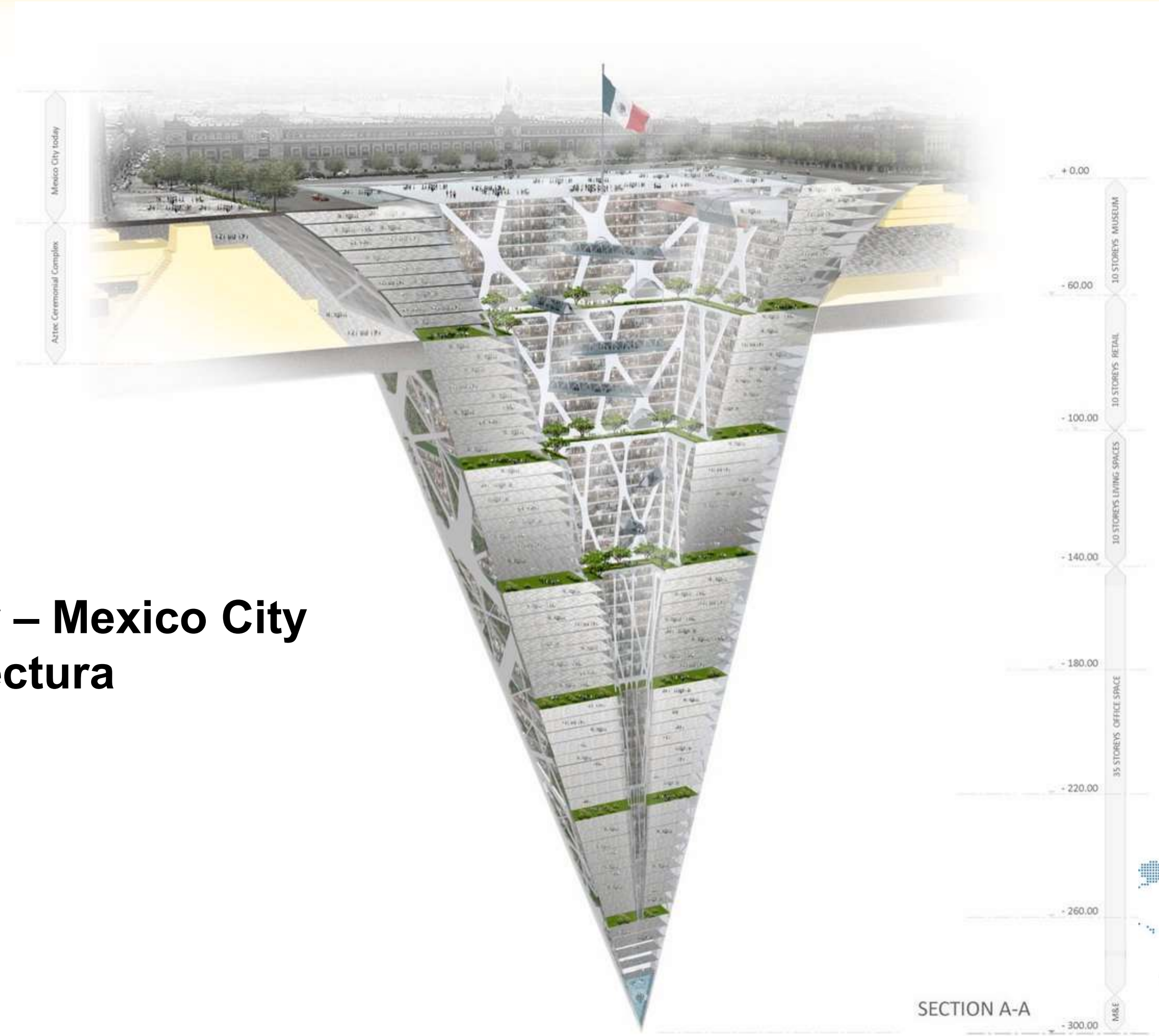
Lalibela Church

© Bet Giyorgis

1.1. Underground buildings

Villa Vals – Vals
Bjarne Mastenbroek


Städel Museum - Frankfurt
schneider + schumacher



Earthscraper – Mexico City
BNKR Aquitectura

1.1. Underground buildings

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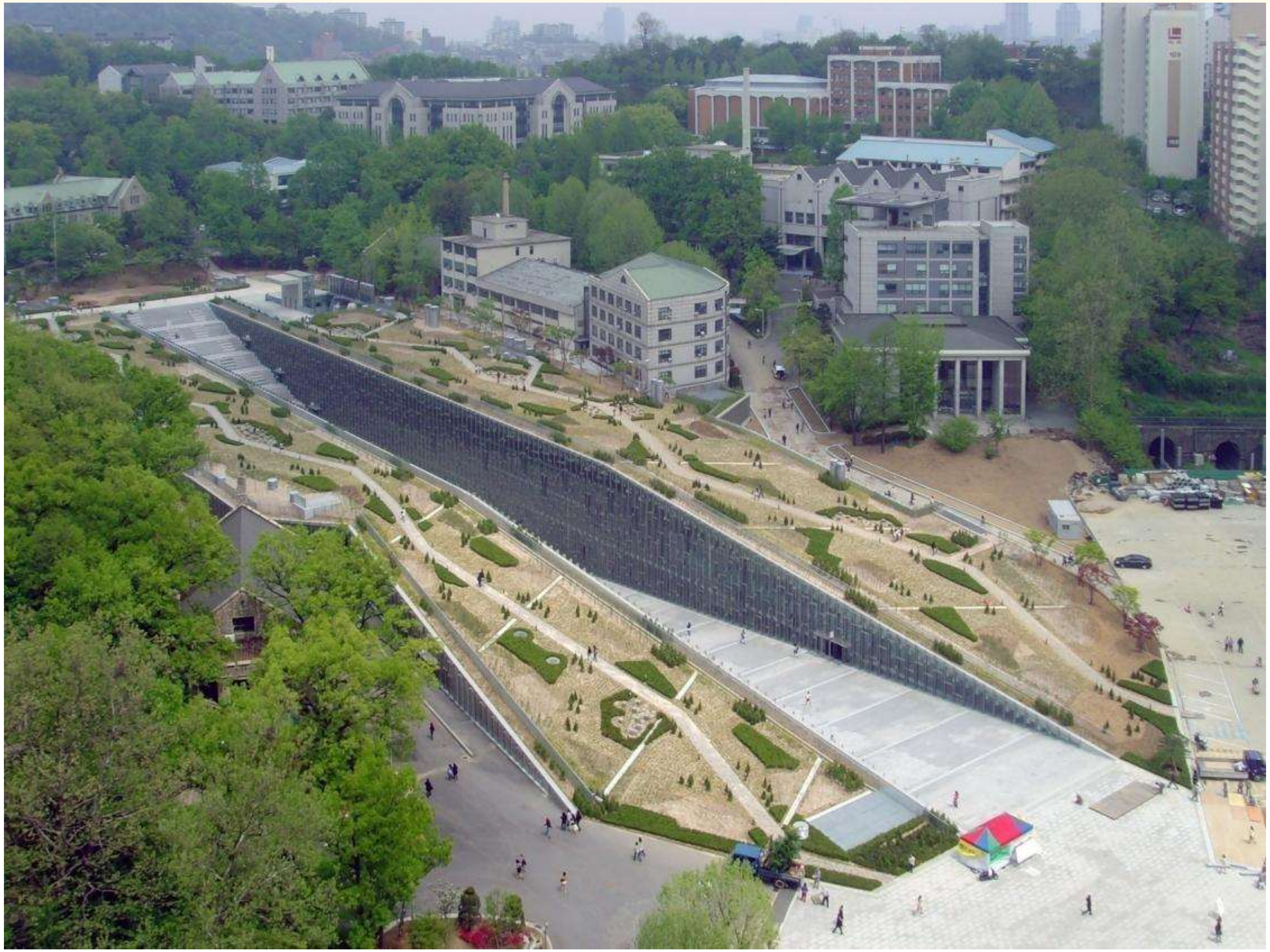
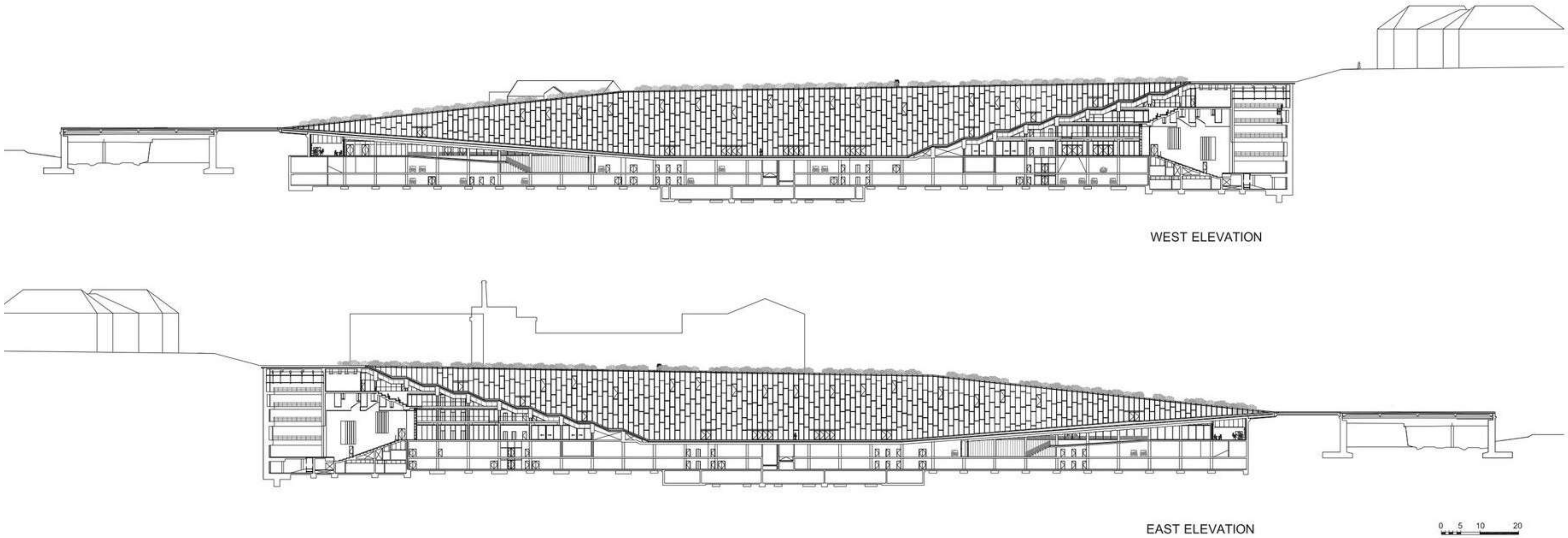


1.1. Underground buildings

1.1. Underground buildings



© DPA

1.1. Underground buildings

Below 10 m, the temperature of the soil is ~constant throughout the year:

$$T_{h<-10\,m} \simeq \frac{1}{\Delta T}\int_{year} T\,dt$$

$$\simeq \frac{T_{max}+T_{min}}{2}$$

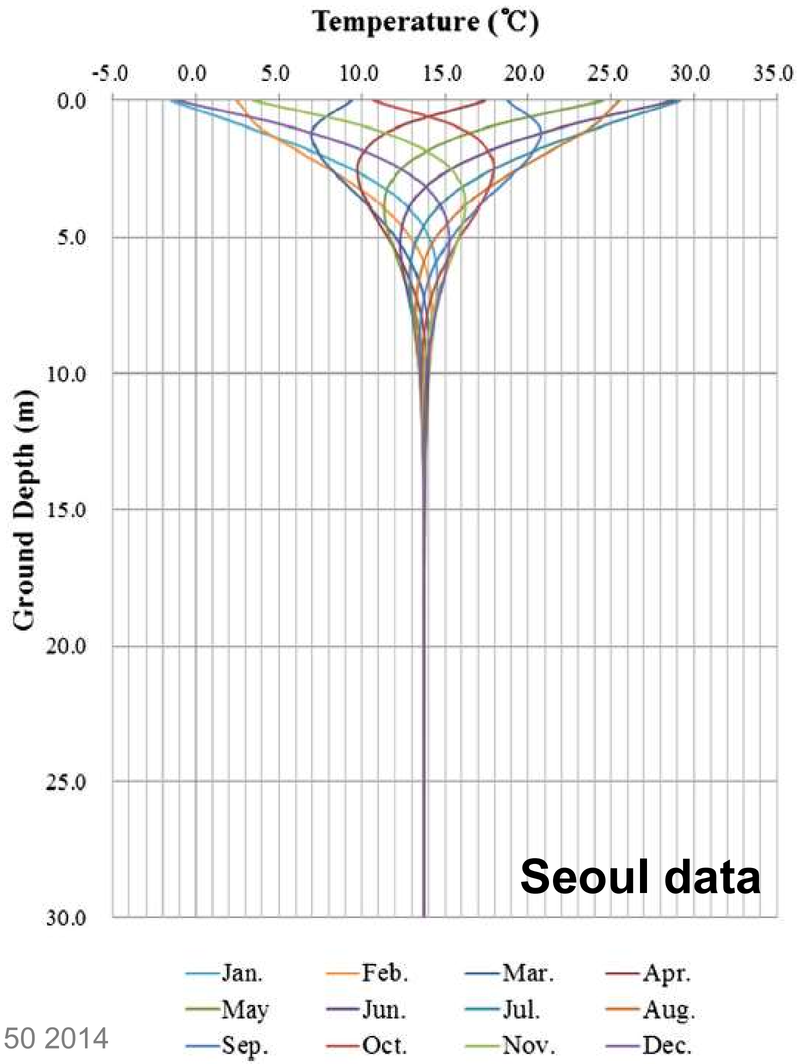
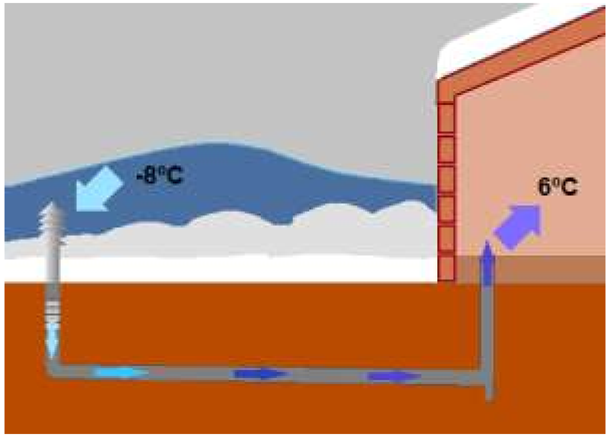
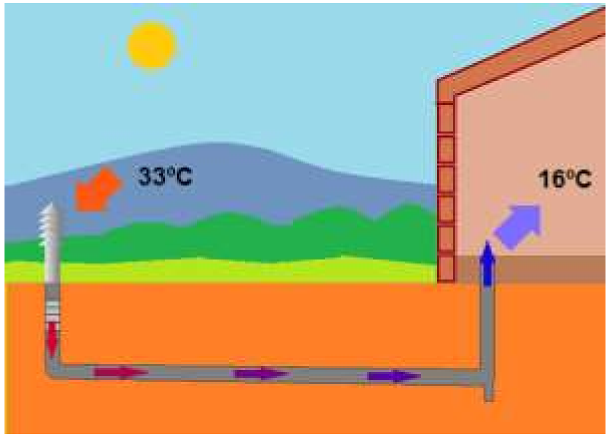


Fig. 7. Distribution of monthly underground temperatures.

Song et al. *Energy Sust. Dvlpt.* **23** 150 2014

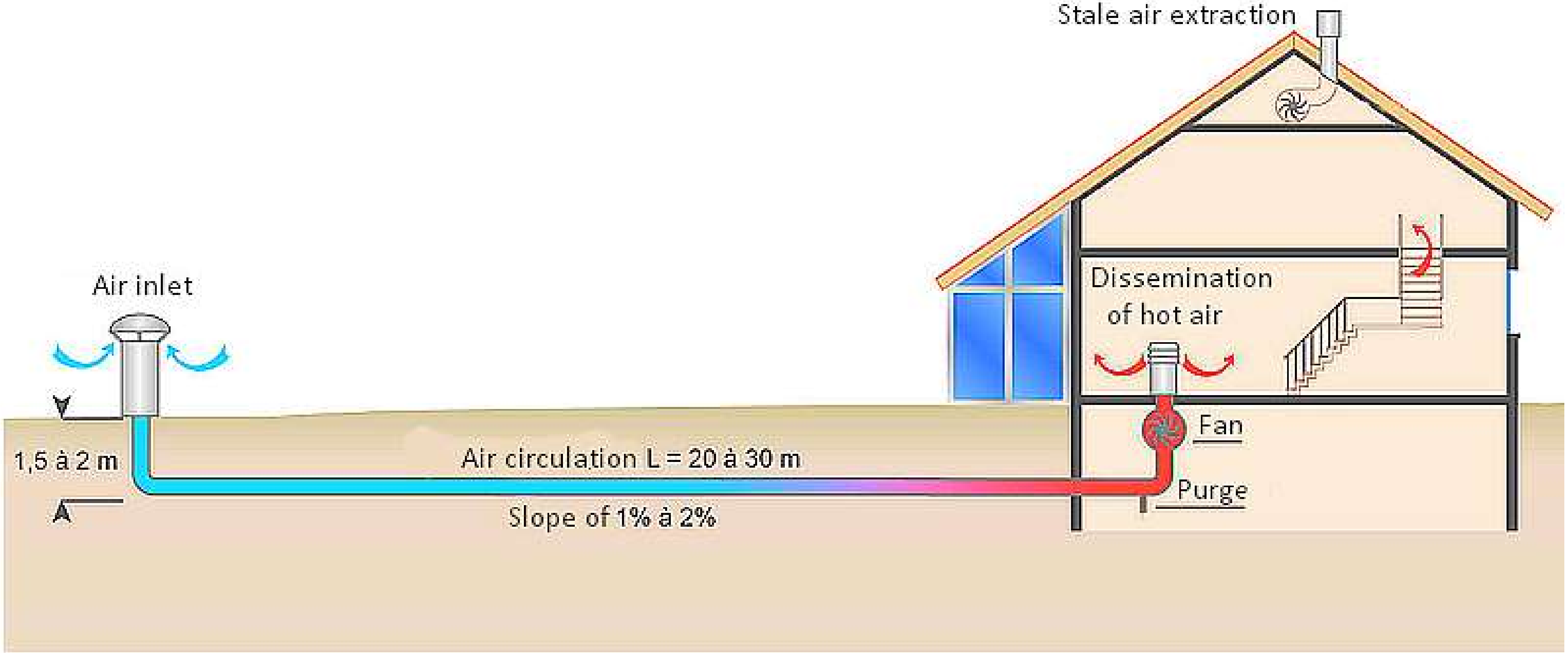
1.2. Thermal Labyrinths / Canadian Wells





Canadian / Provençal Well

1.2. Thermal Labyrinths / Canadian Wells



Canadian / Provençal Well

1.2. Thermal Labyrinths / Canadian Wells

Data for the calculation :

$$T_{soil} = 15°\mathrm{C}$$

$$S_{house} = 100\, m^2$$

$$h_{house} = 3\, m$$

$$Air\, renewal\, rate = 4\, Vol/h$$

$$D_{PVC} = 0.2\, m$$

$$\lambda_{PVC} = 0.19\, W/m.K$$

$$e_{PVC} = 2\, mm$$

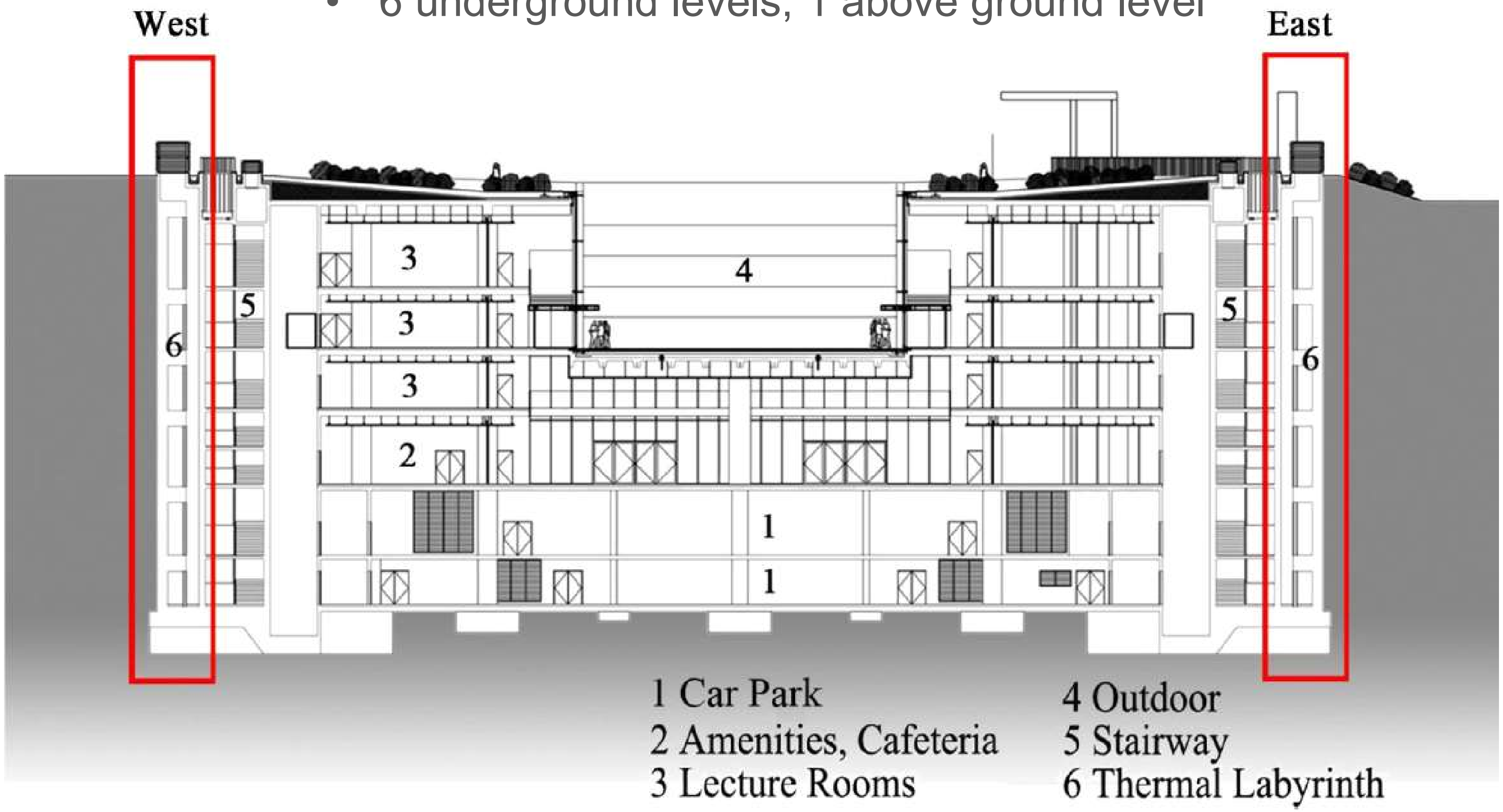
$$\rho_{p,air} = 1.2\, kg/m^3$$

$$c_{p,air} = 29\, kJ/kg.K$$

1.2. Thermal Labyrinths / Canadian Wells

Ewha Womans University:

- 69’000 m²
- 6 underground levels, 1 above ground level



Song et al. *Energy Sust. Dvlpt.* **23** 150 2014

1.2. Thermal Labyrinths / Canadian Wells

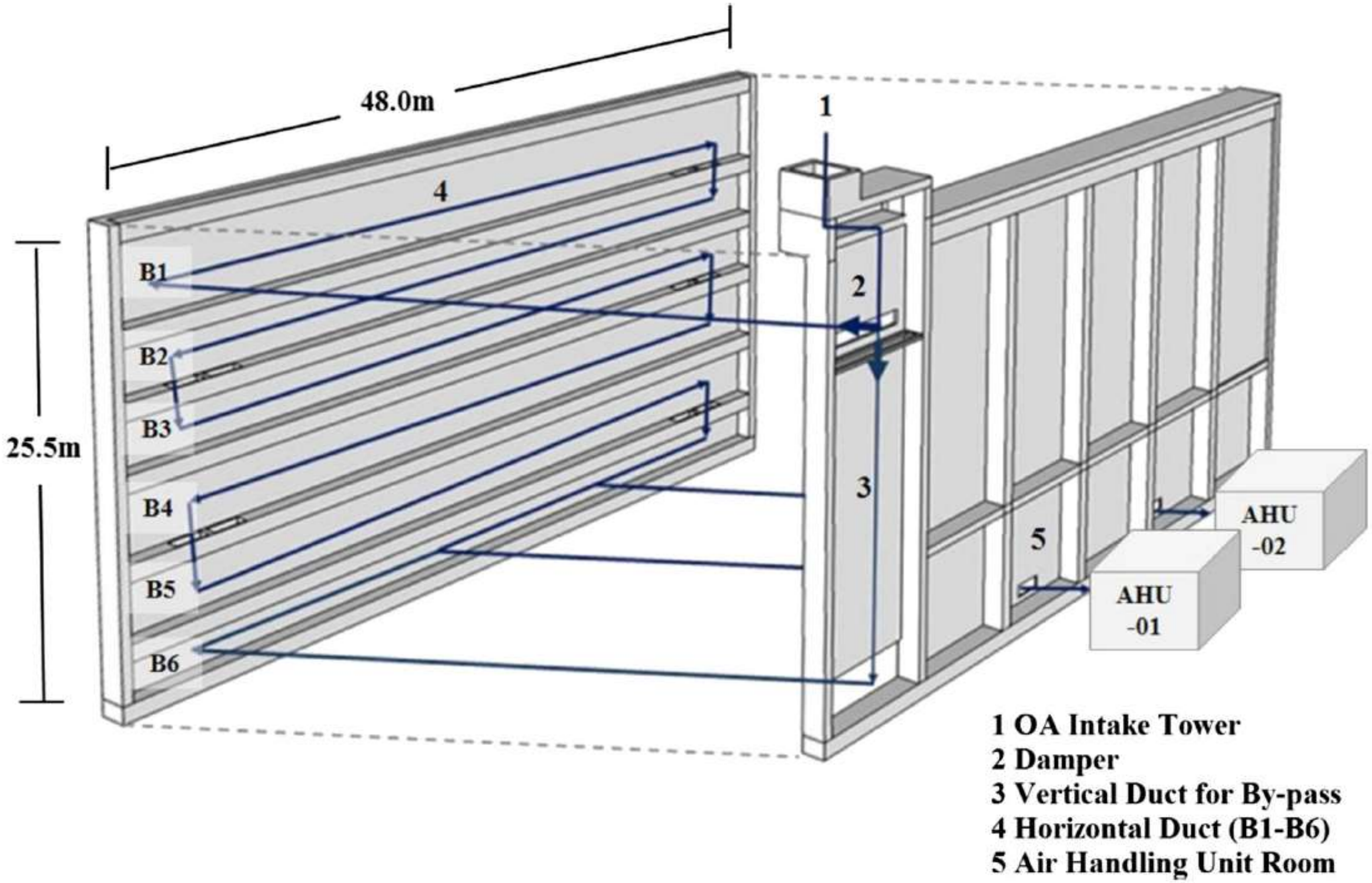


Fig. 4. OA intake channels of the measured TLVS.

Song et al. *Energy Sust. Dvlpt.* **23** 150 2014

1.2. Thermal Labyrinths / Canadian Wells

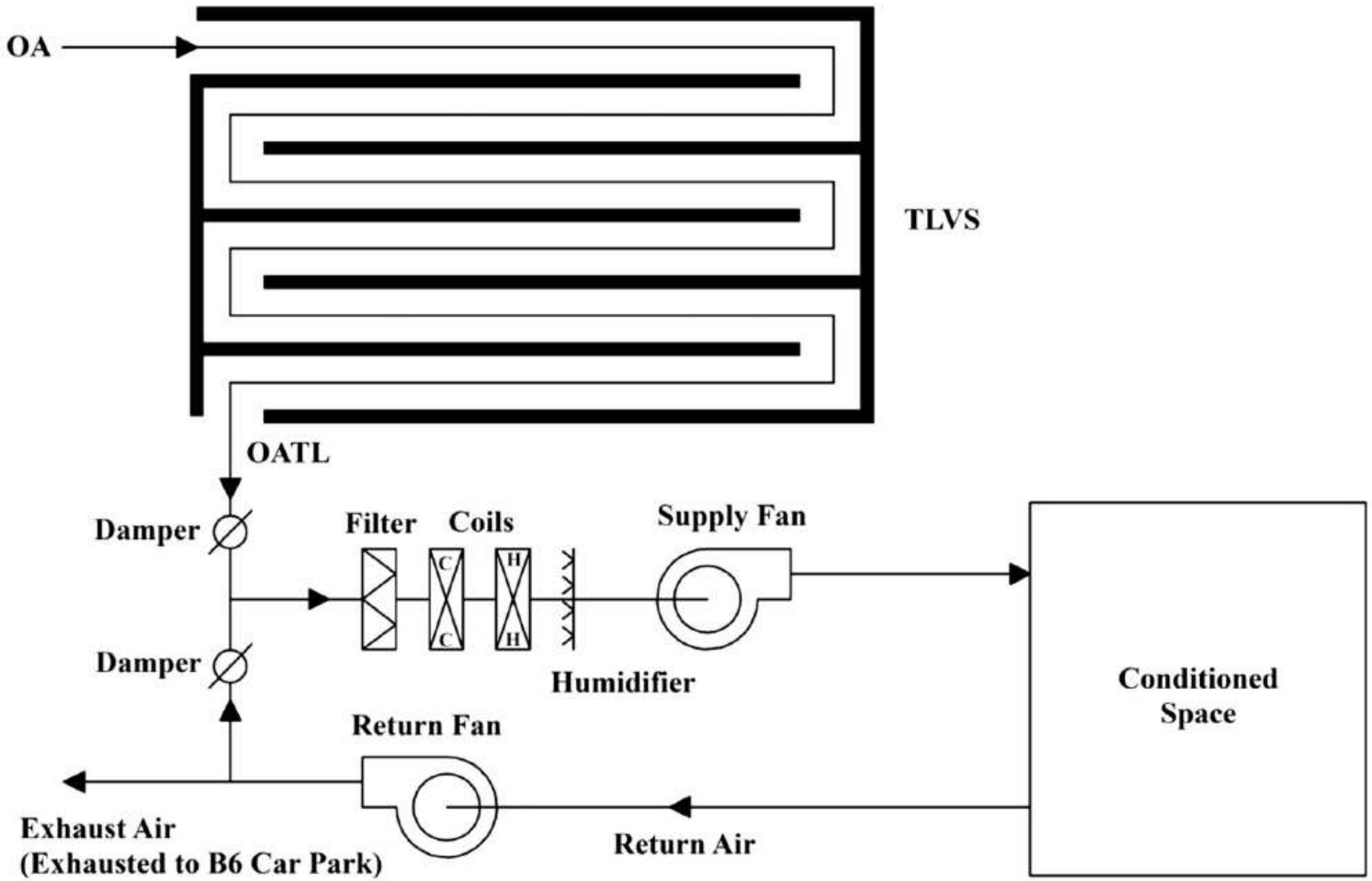
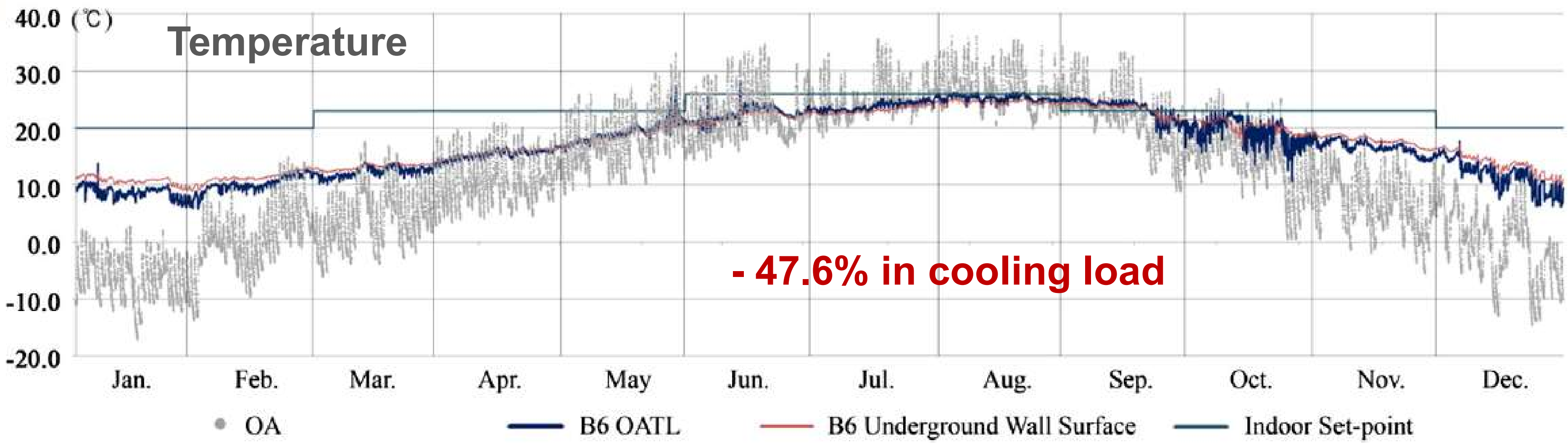
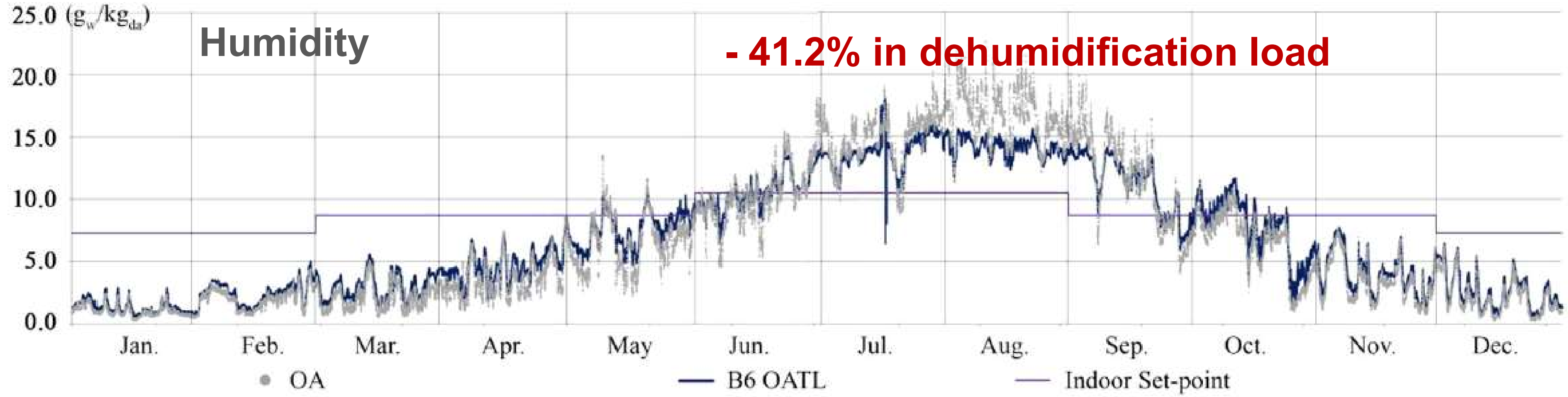


Fig. 5. Air flow diagram that includes the measured TLVS.

Song et al. *Energy Sust. Dvlpt.* **23** 150 2014

1.2. Thermal Labyrinths / Canadian Wells



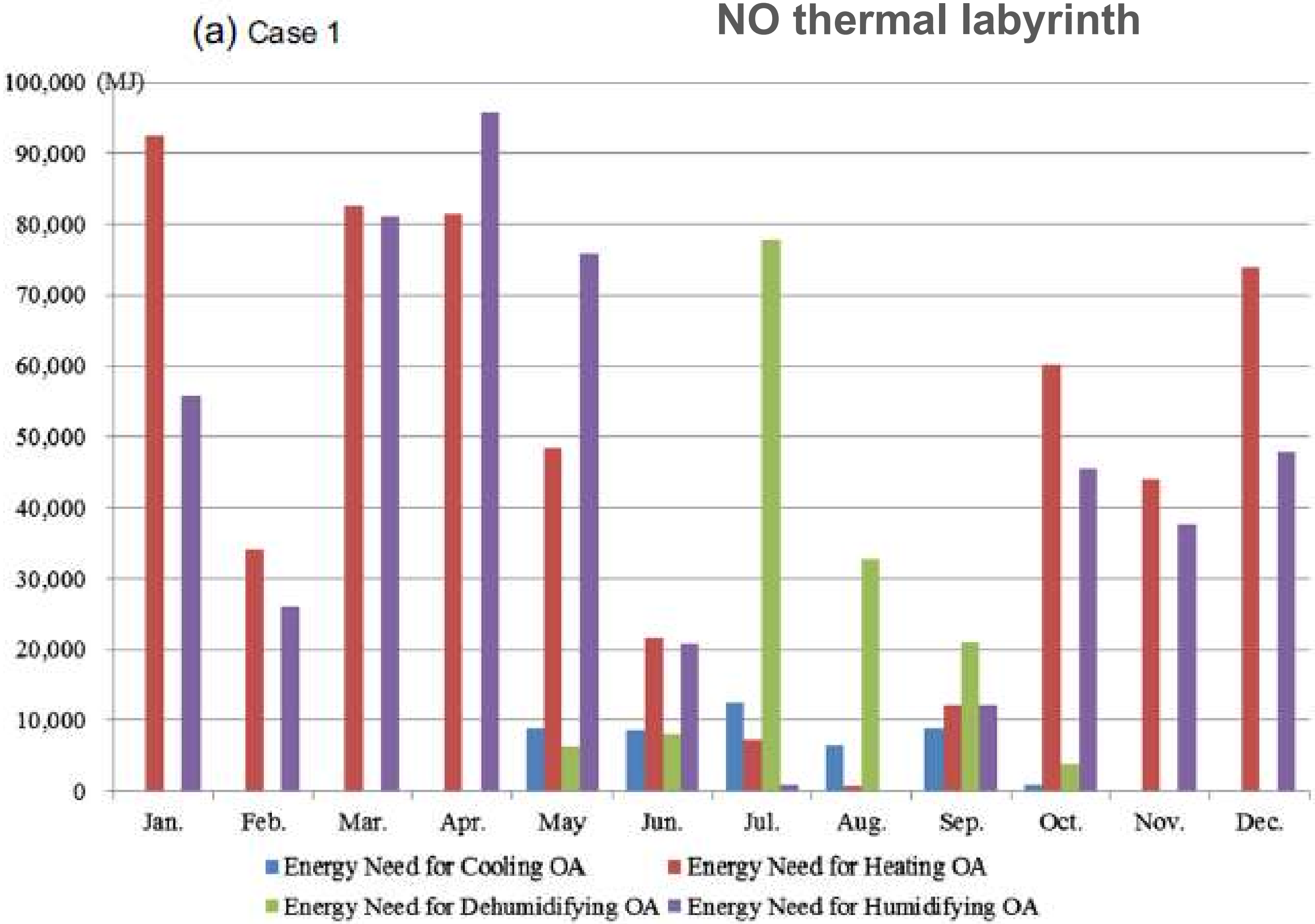


- Outdoor air above ground
- Outdoor air through TLVS

Song et al. *Energy Sust. Dvlpt.* **23** 150 2014

1.2. Thermal Labyrinths / Canadian Wells

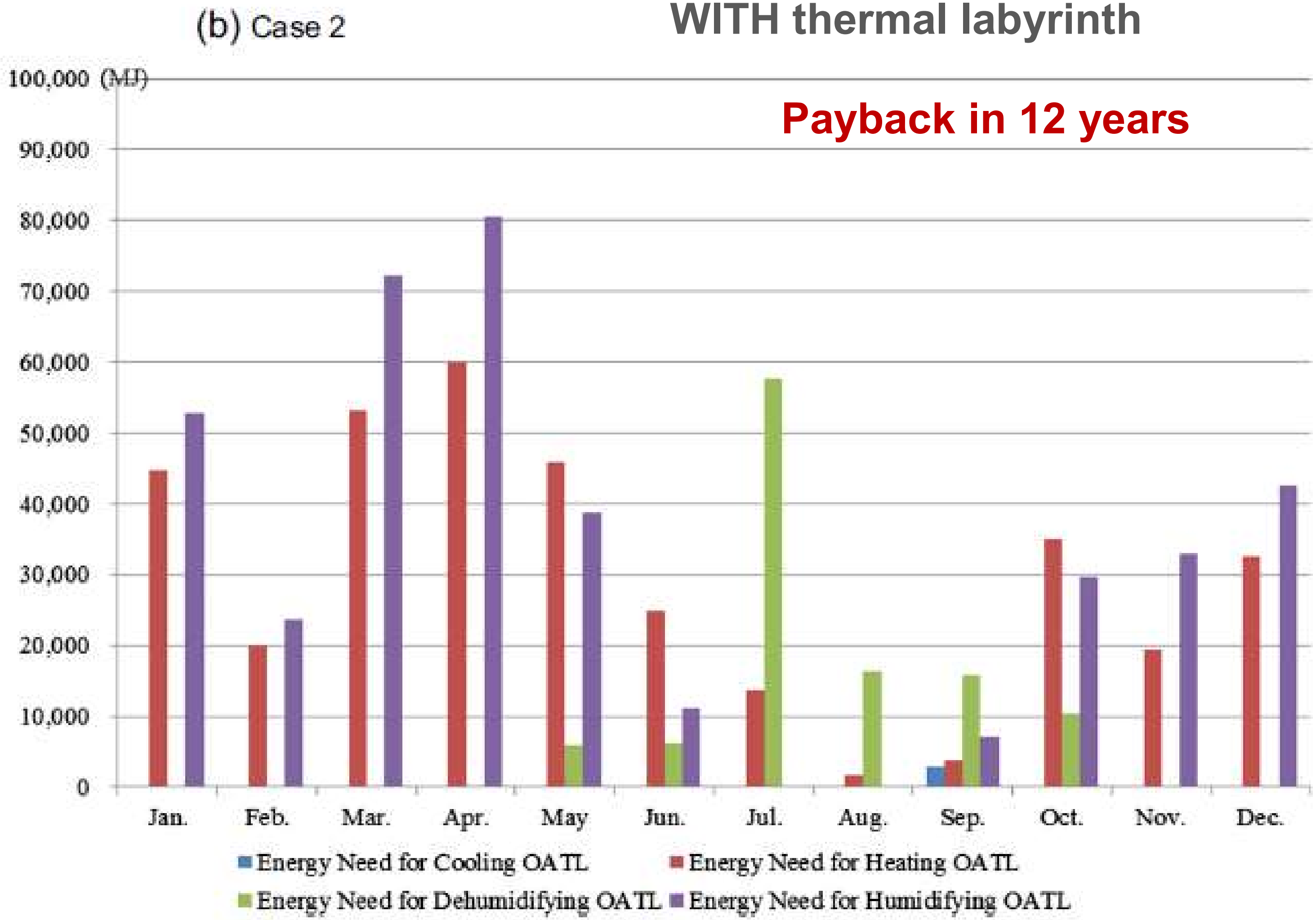
NO thermal labyrinth



Song et al. *Energy Sust. Dvlpt.* **23** 150 2014

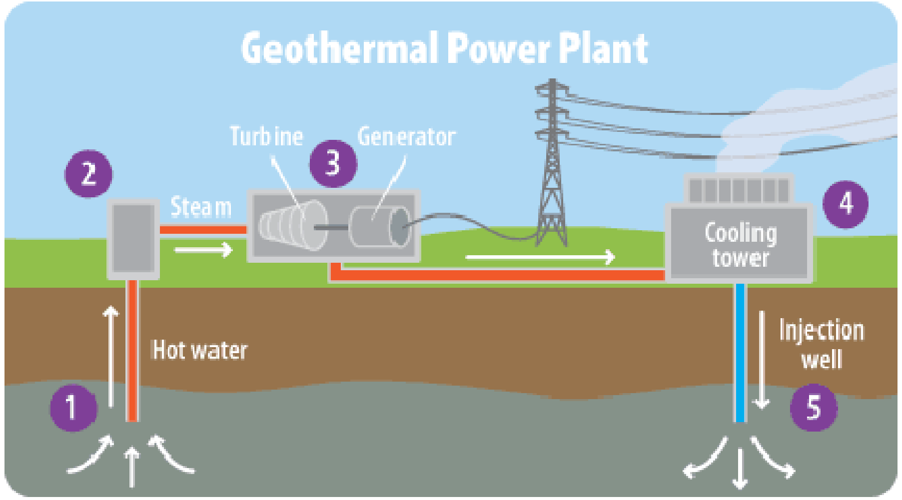
1.2. Thermal Labyrinths / Canadian Wells

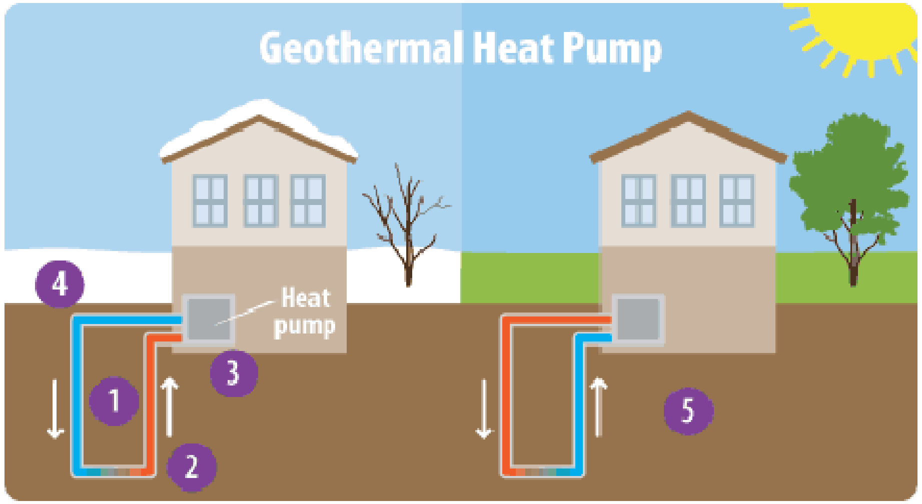
WITH thermal labyrinth



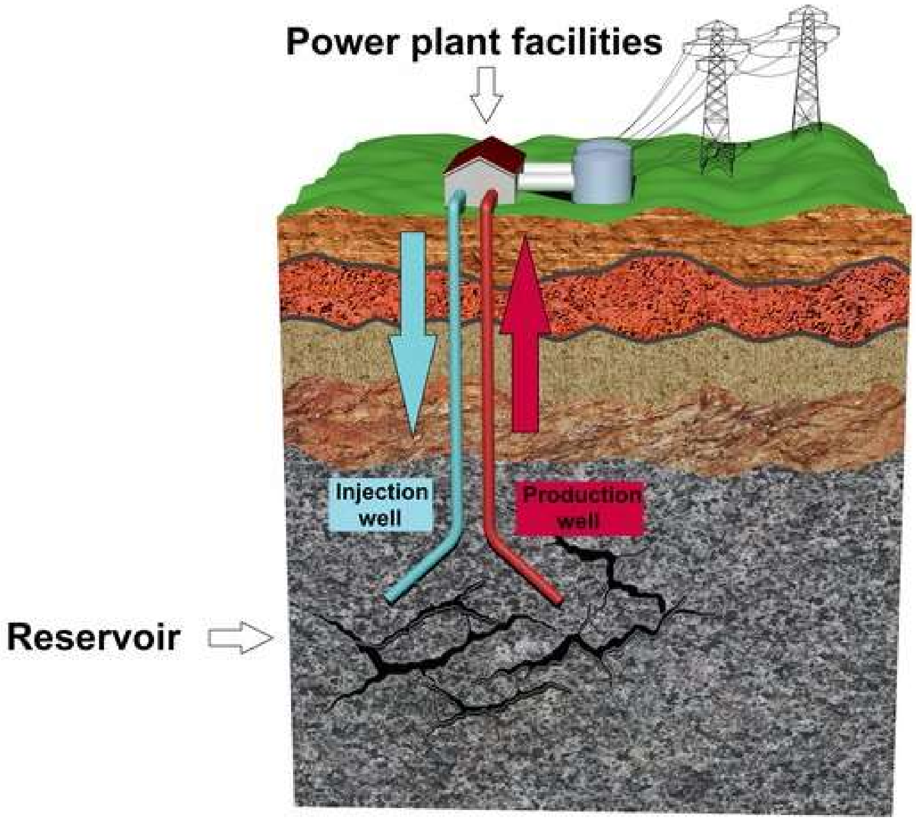
Song et al. *Energy Sust. Dvlpt.* **23** 150 2014

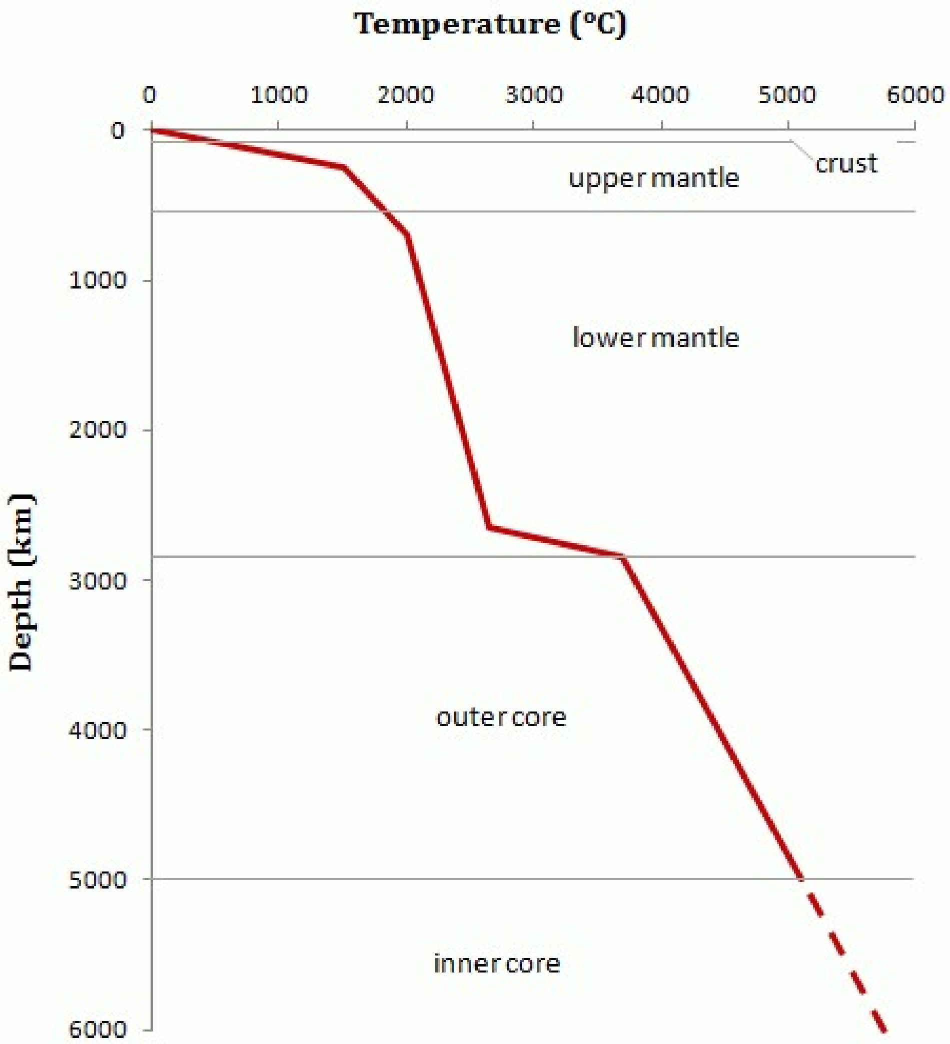
Geothermal ≠ Geothermal





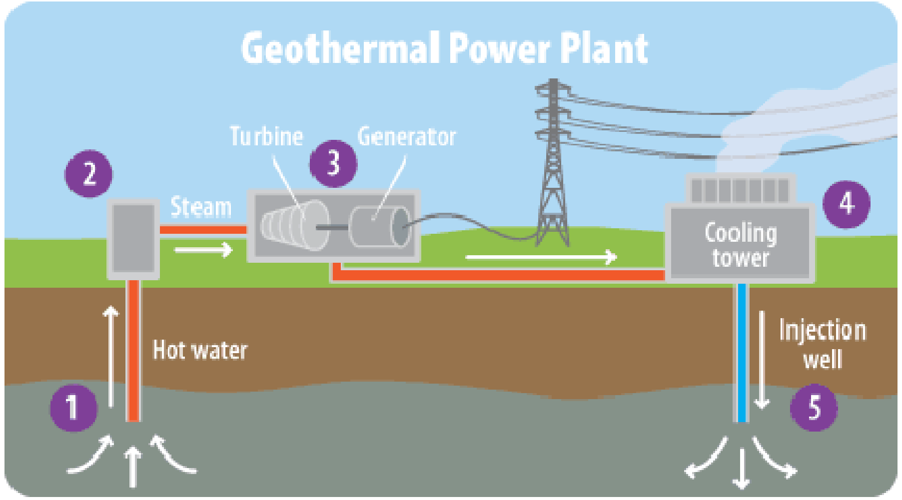
Deep geothermal systems

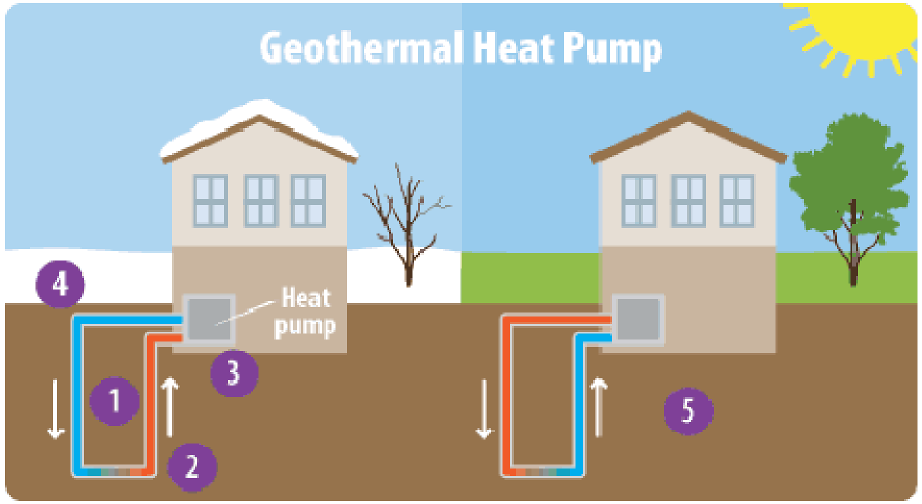




Vitaller *Open Access Metall. J.* **9** 331 2019

Geothermal ≠ Geothermal



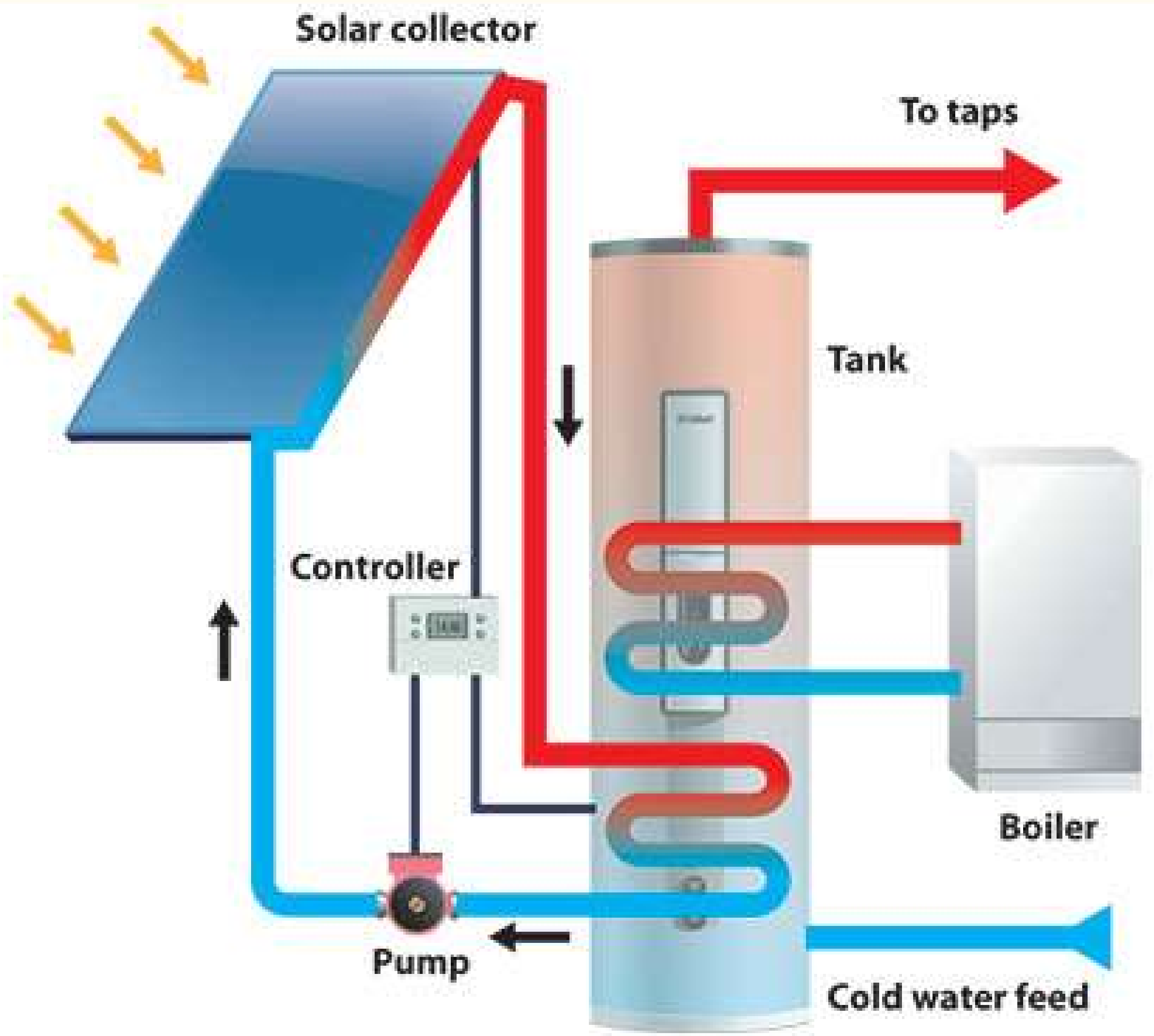


1 plant ~ 50-100 MW

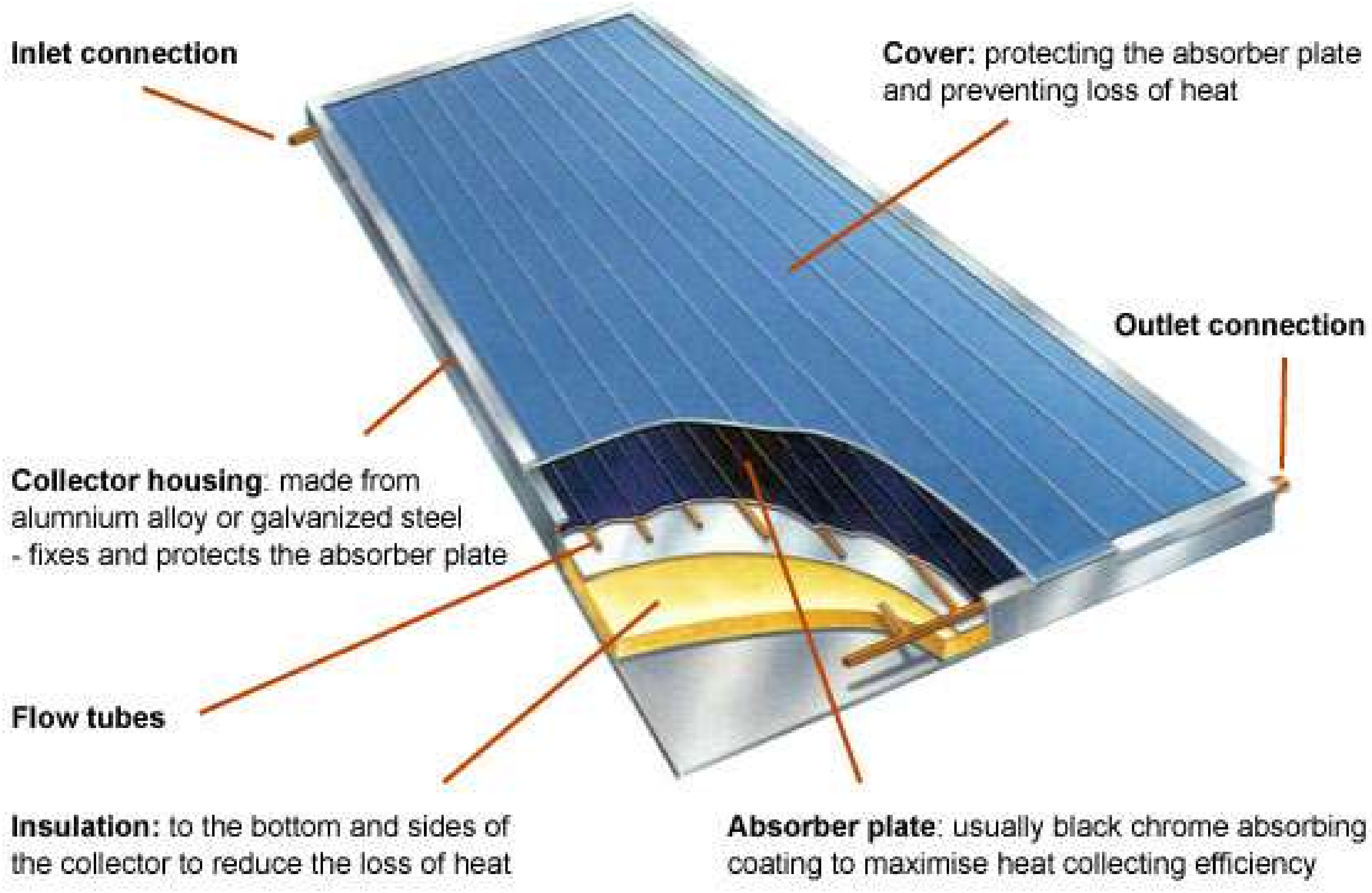
1 installation ~ 10-500 kW

2. SOLAR THERMAL COLLECTORS

2. Solar thermal collectors



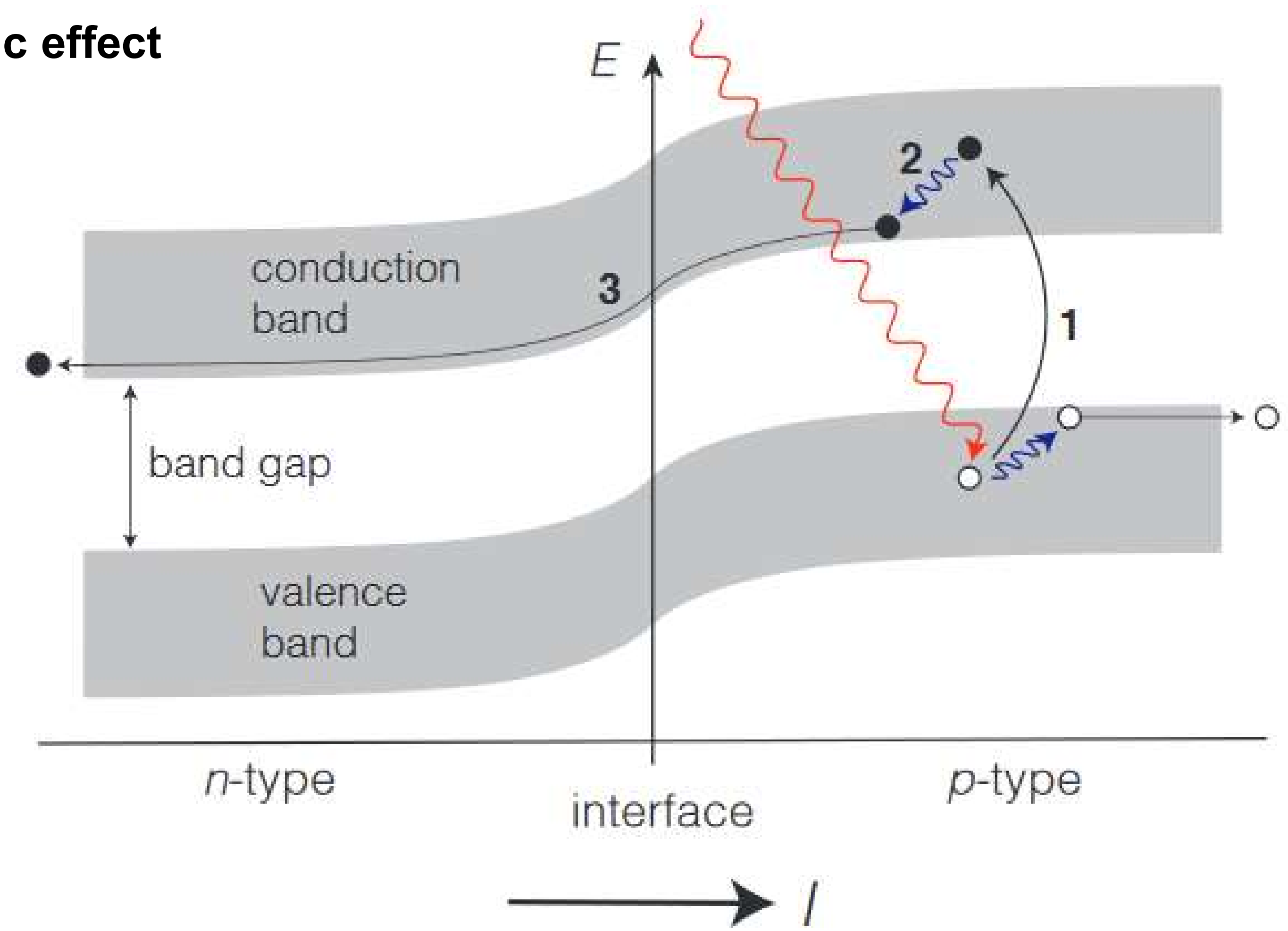
2. Solar thermal collectors



3. PHOTOVOLTAIC PANELS

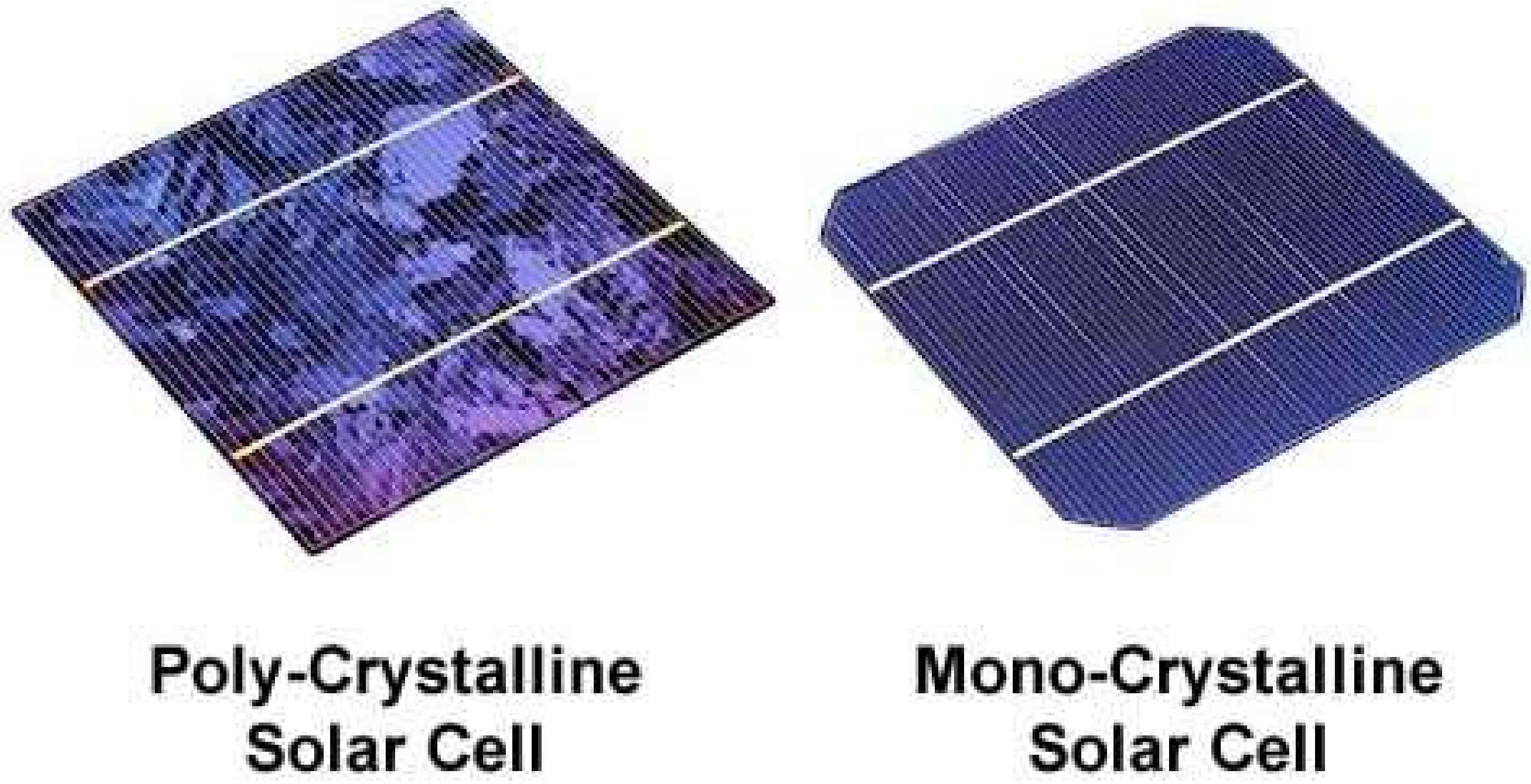
1. Different PV types
2. Efficiency
3. Caveats

Photovoltaic effect



Alicki et al. *Ann. Phys.* **378** 71 2017

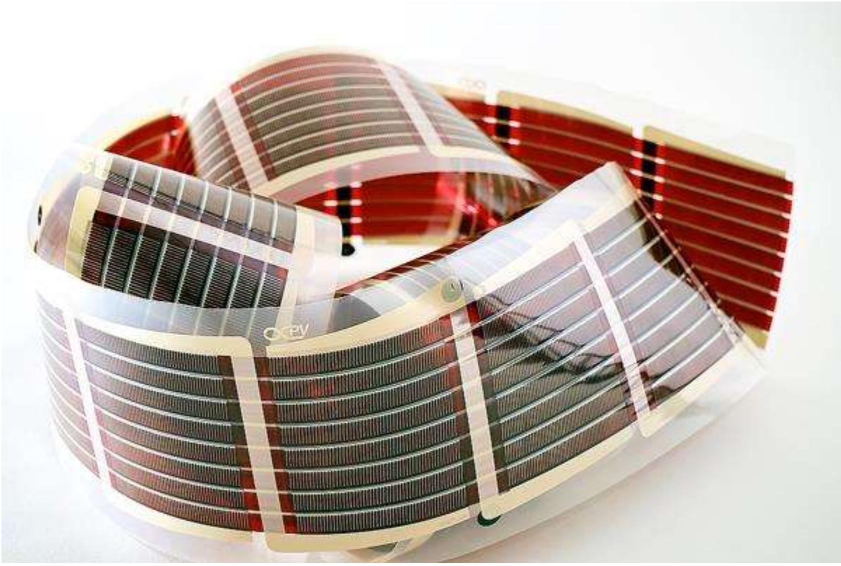
Crystalline Si-based PV



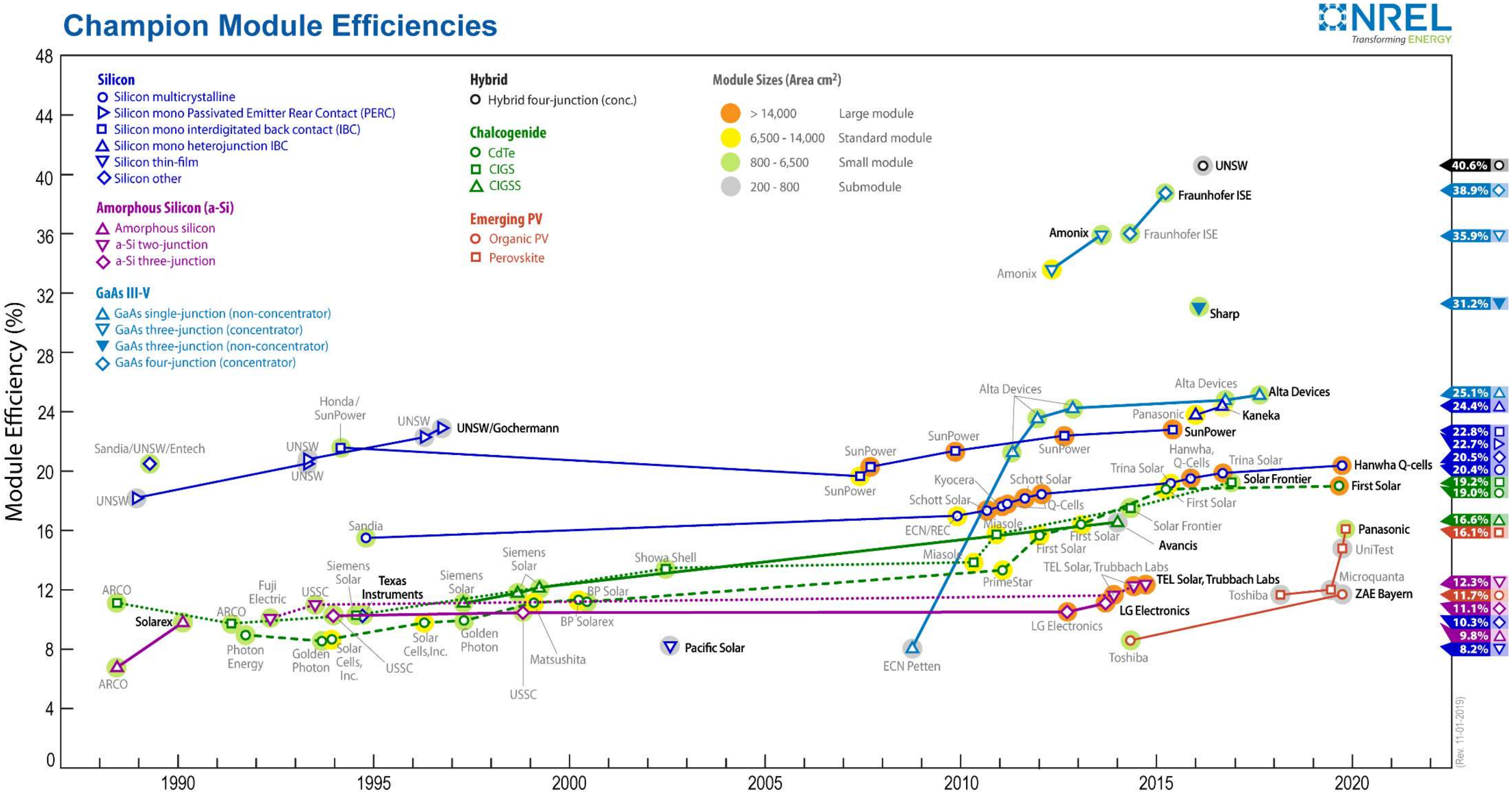
Amorphous Si-based PV

© Onyx

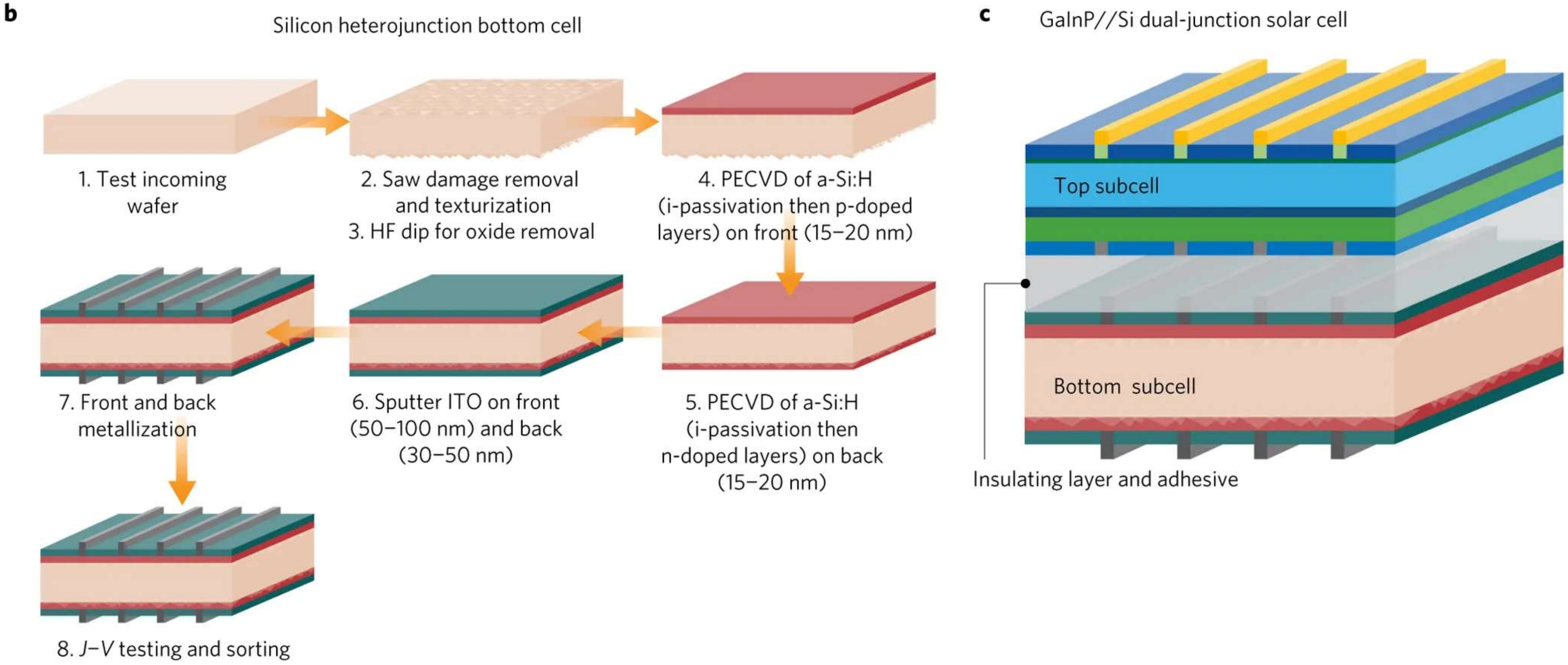
Organic PV



3.2. Efficiency

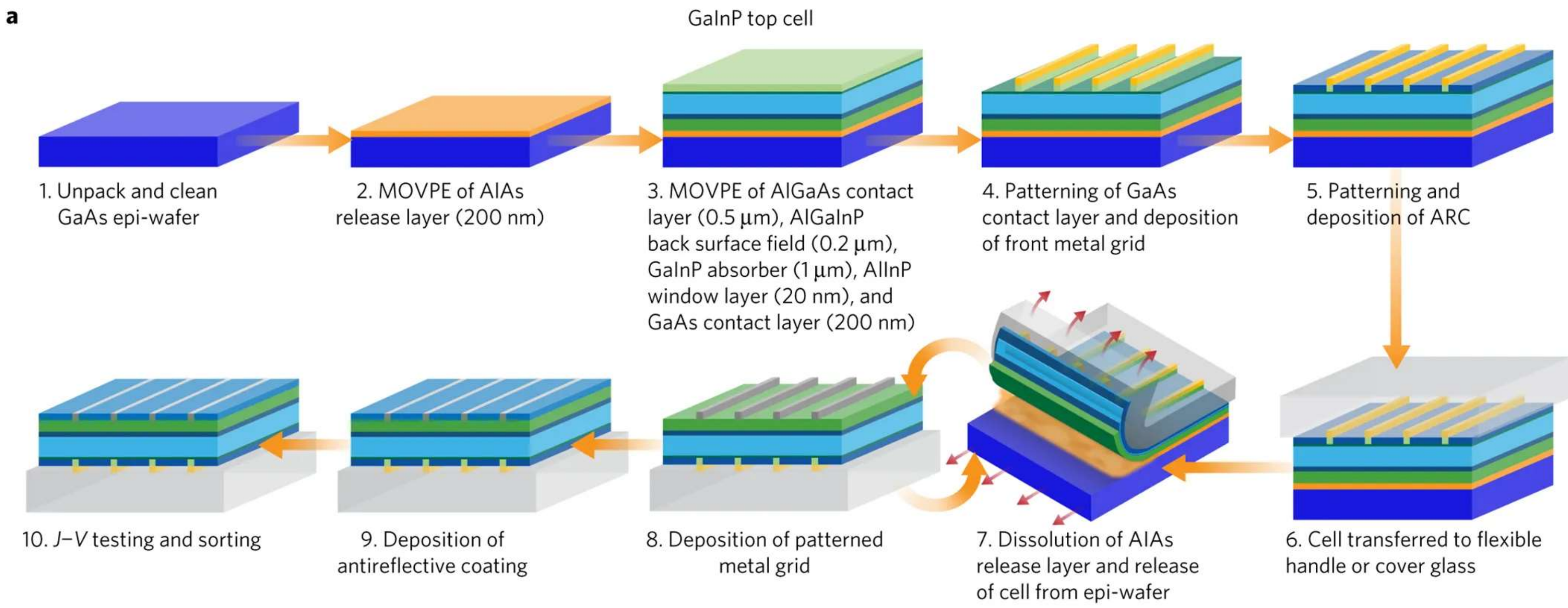


Si PV panels



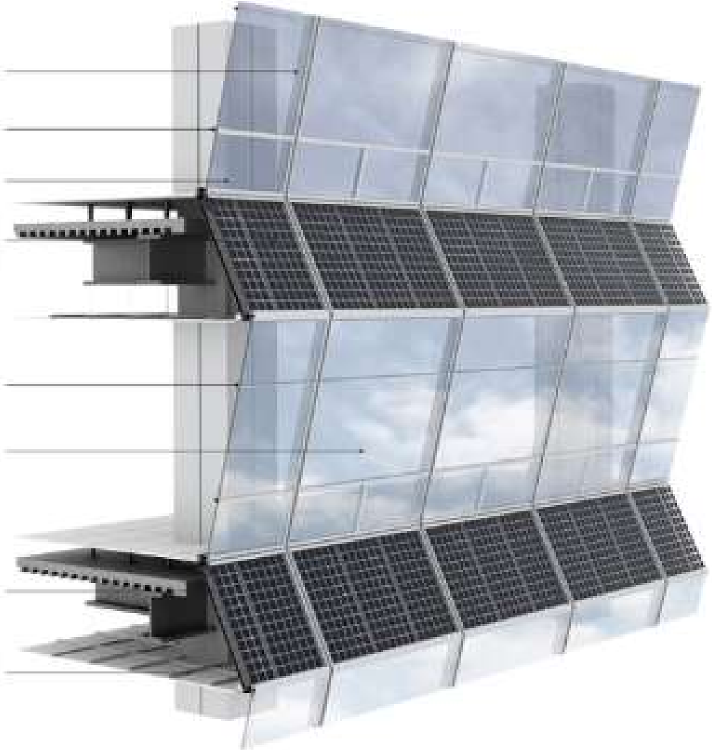
Essig *Nature Energy* **2** 17144 2017

GaAs PV panels



Essig *Nature Energy* **2** 17144 2017

3.3. Caveats

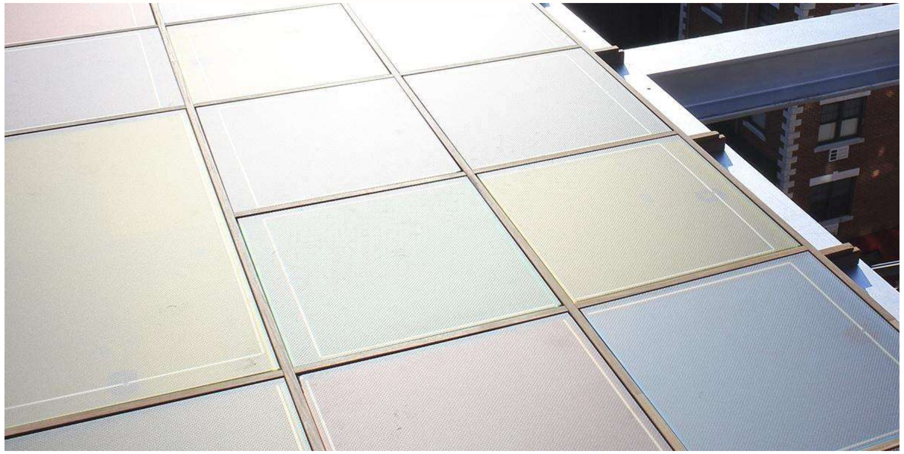


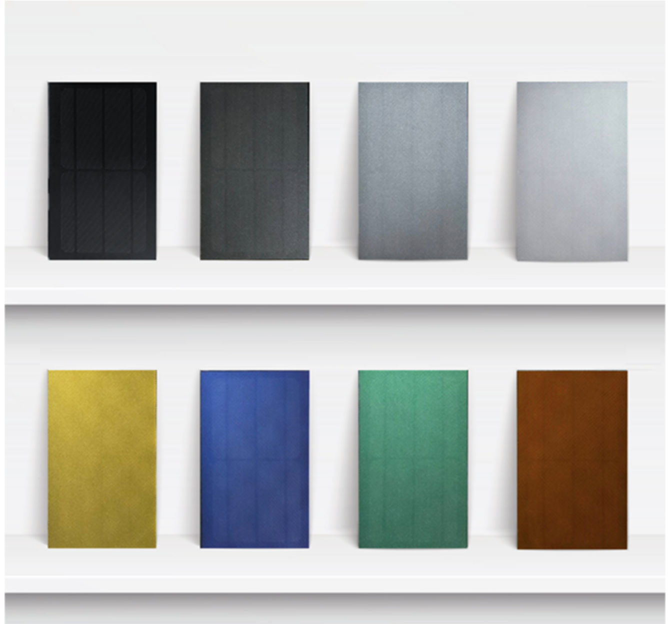
FKI Tower - Seoul

Palais de Justice - Paris
© RPBW

Palais de Justice - Paris
© Guillaume David

3.3. Caveats


© Onyx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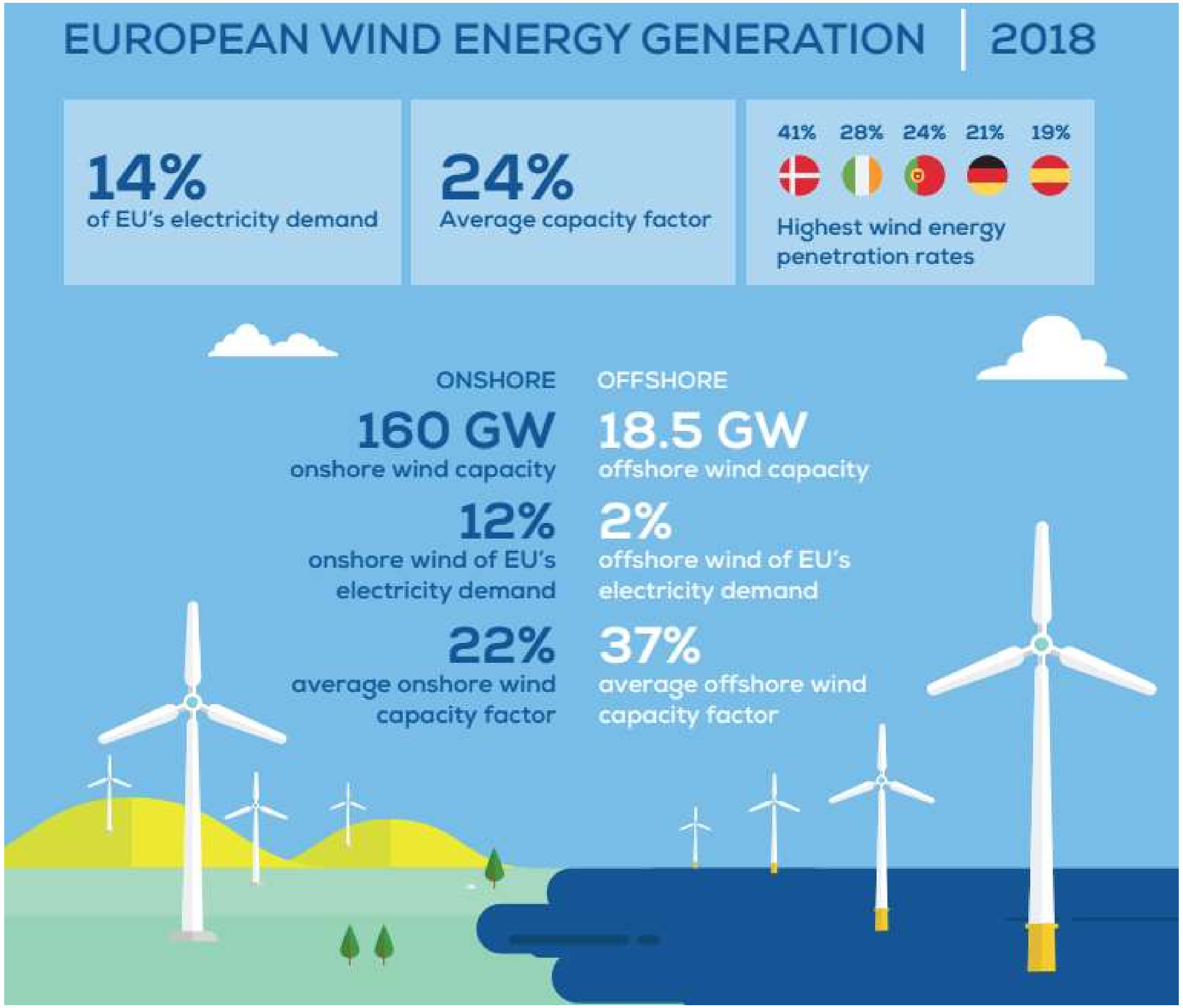
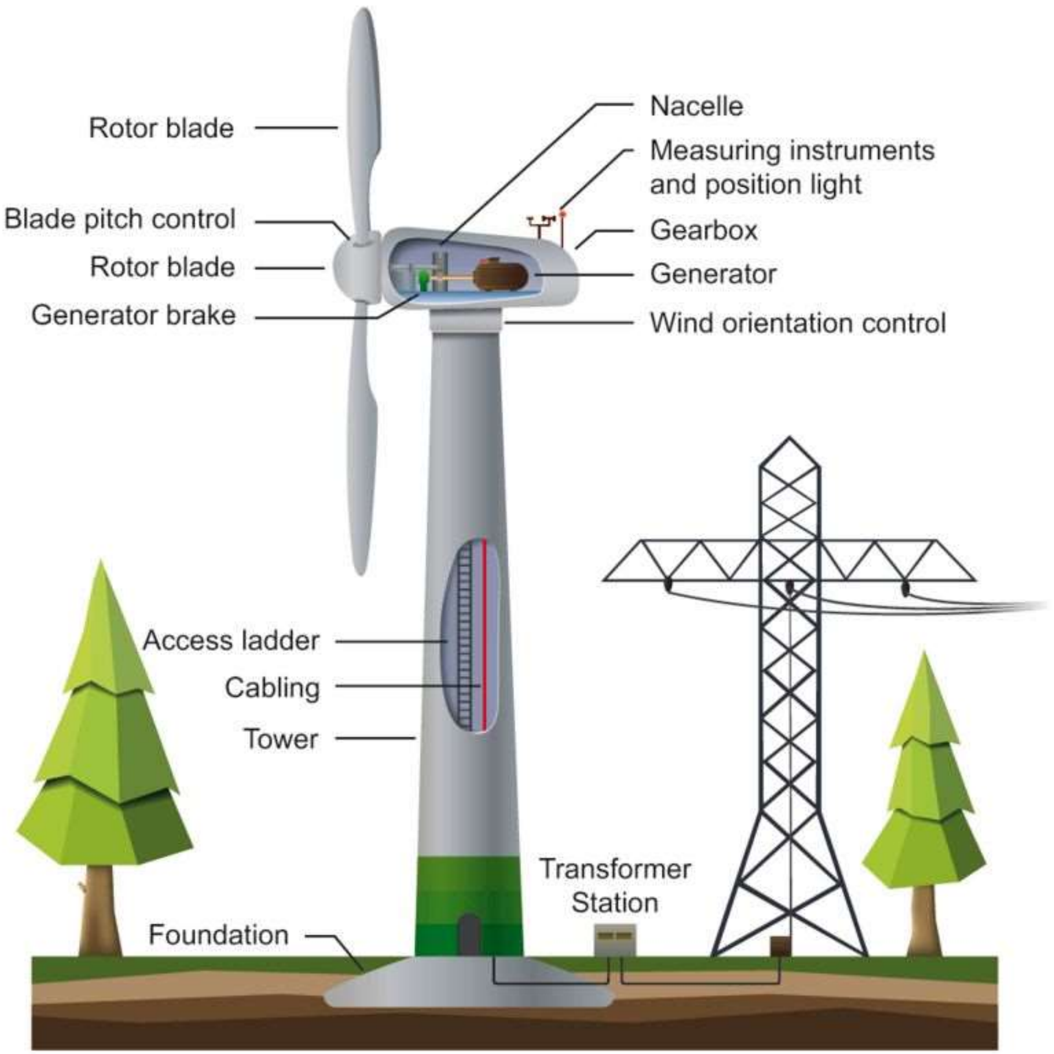
4. WIND TURBINES

1. How do they work
2. Production
3. Caveats

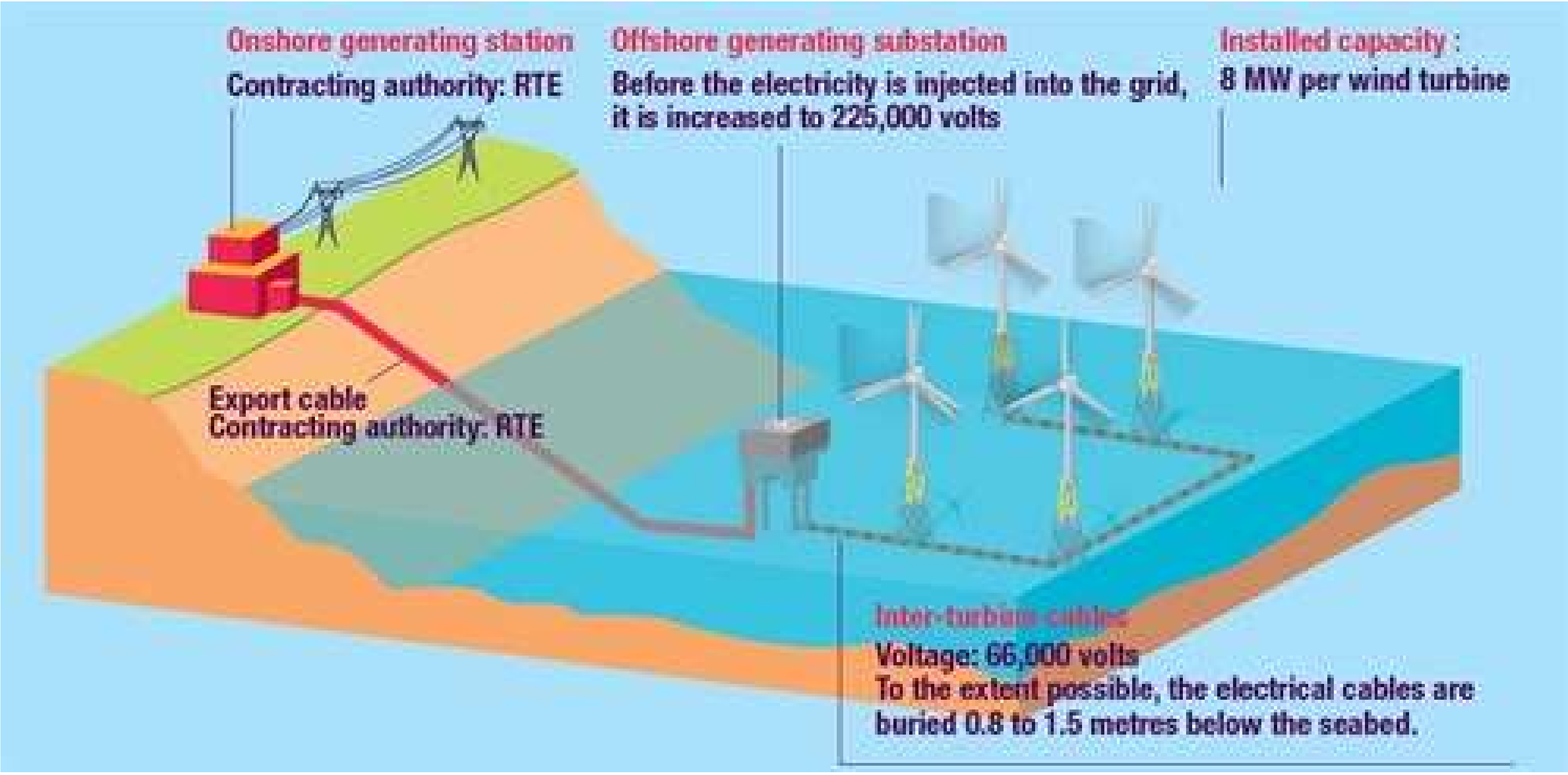
4.1. How do they work?



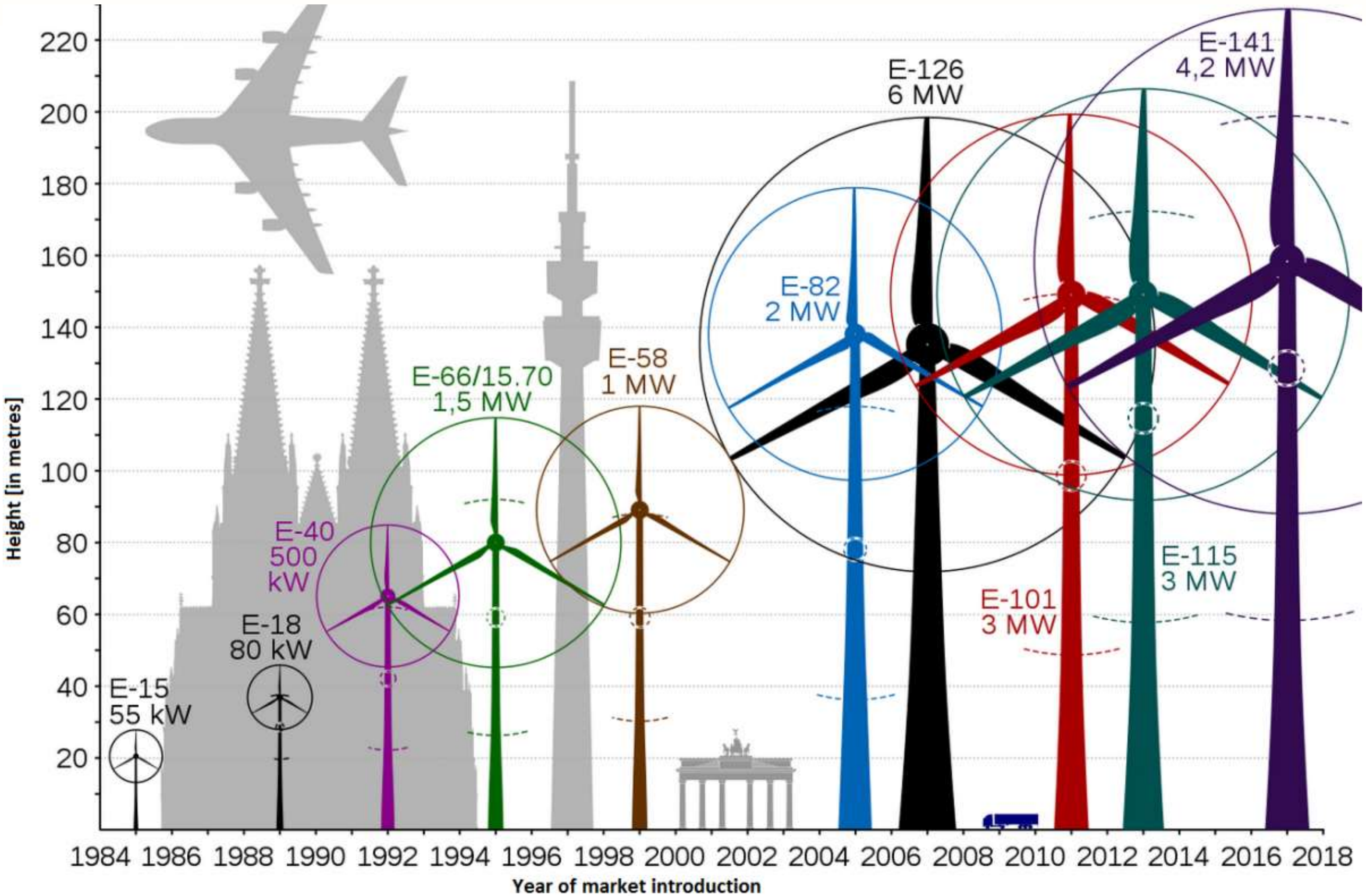
4.1. How do they work?



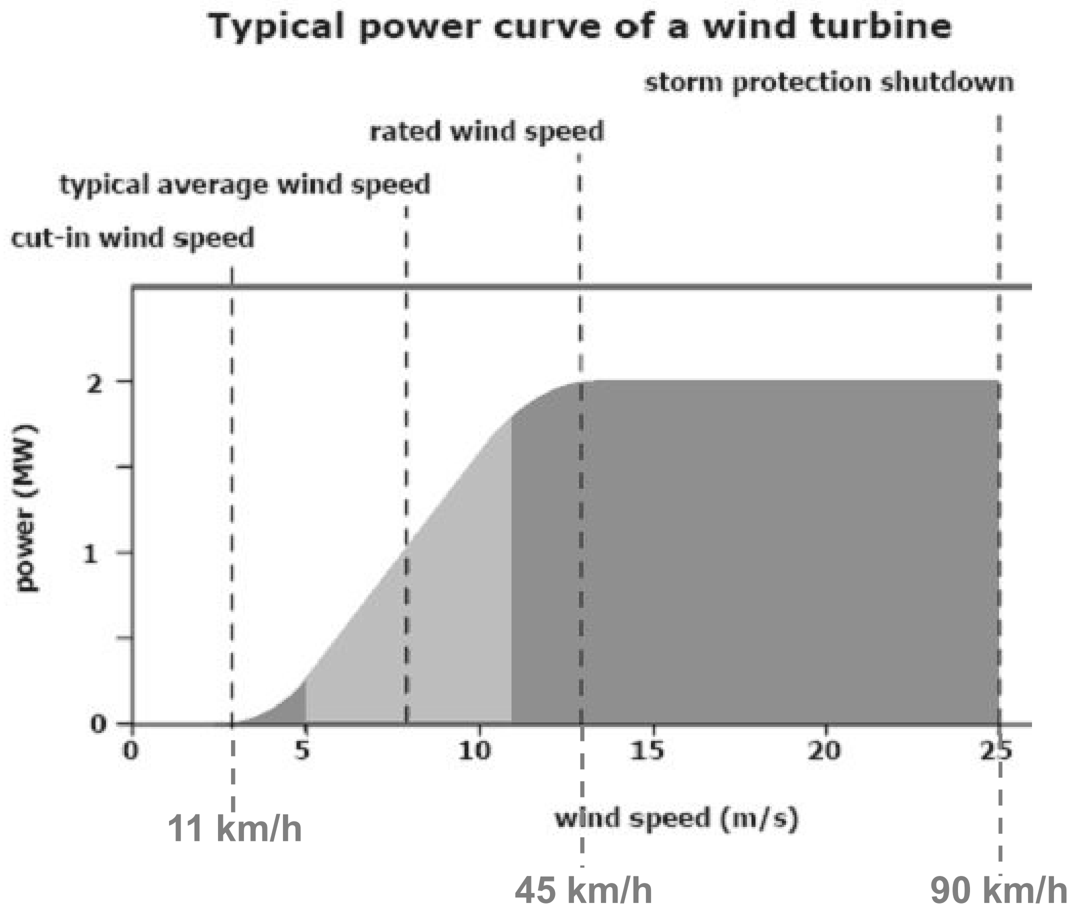
Saint-Brieuc Bay offshore wind project



4.2. Production

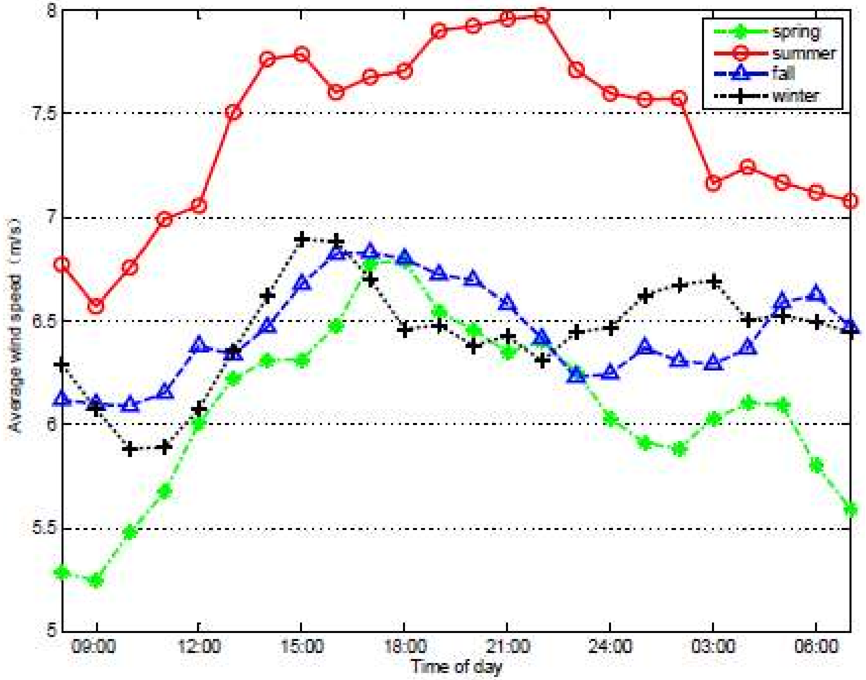


Minimum and maximum wind speed



Intermittence

Zhoushan islands (China)



(a) average wind speed

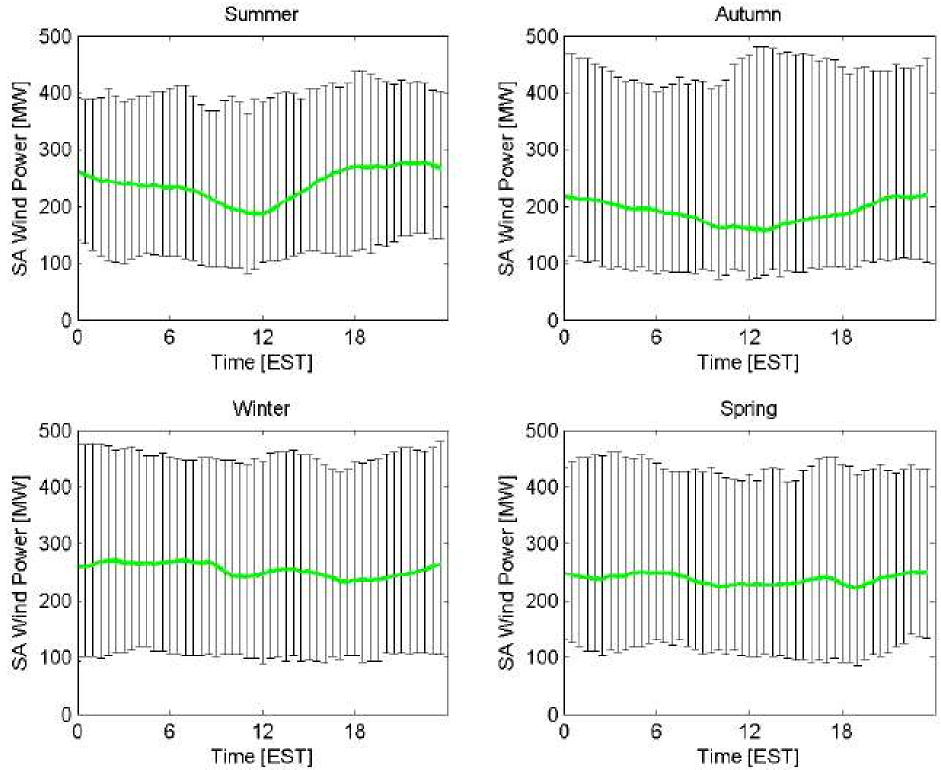
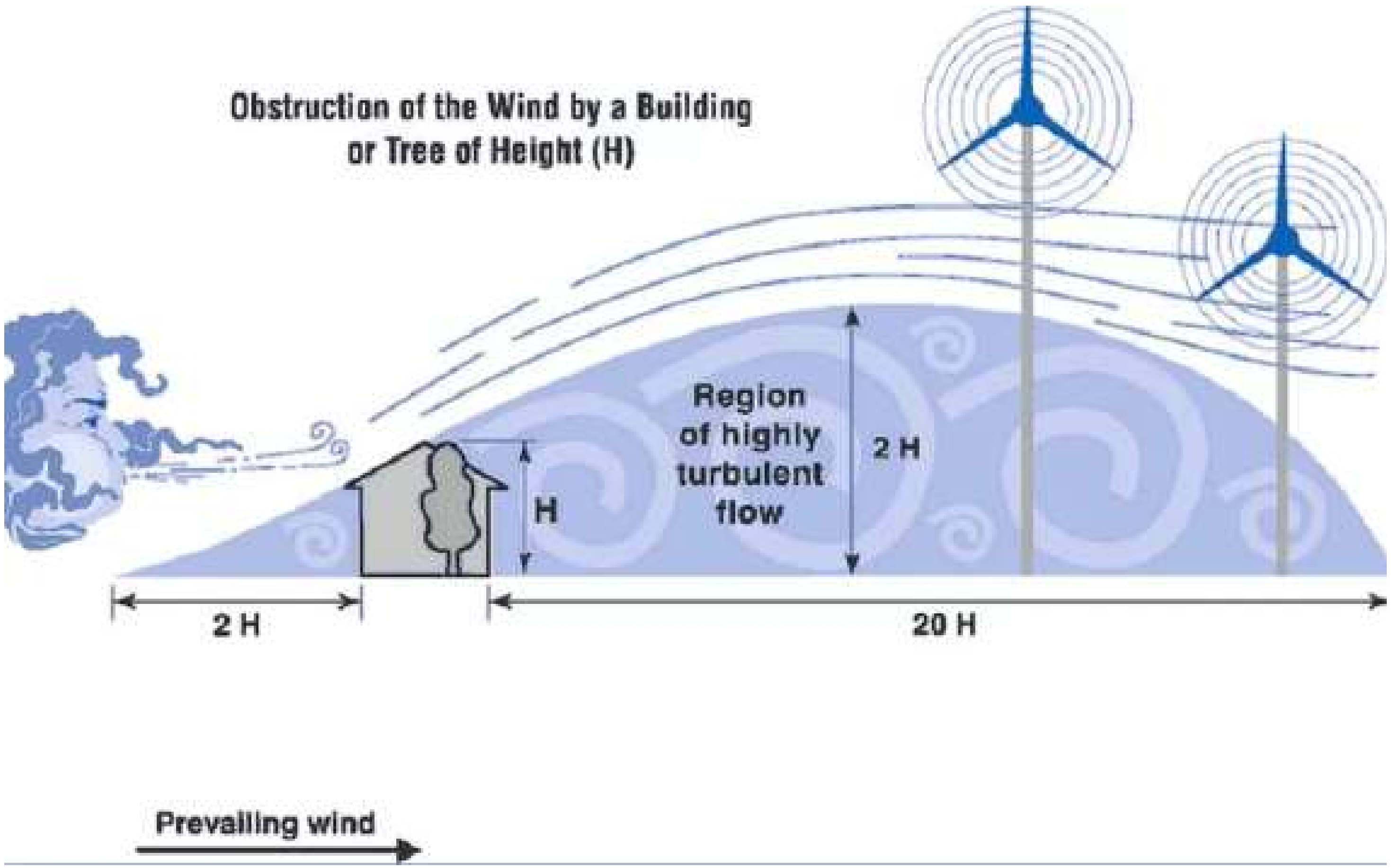


Figure 18: The average SA daily total wind power generation profile for each season in 2008-9 with the error bars indicating 2 standard deviations of the data points lying above and below the average

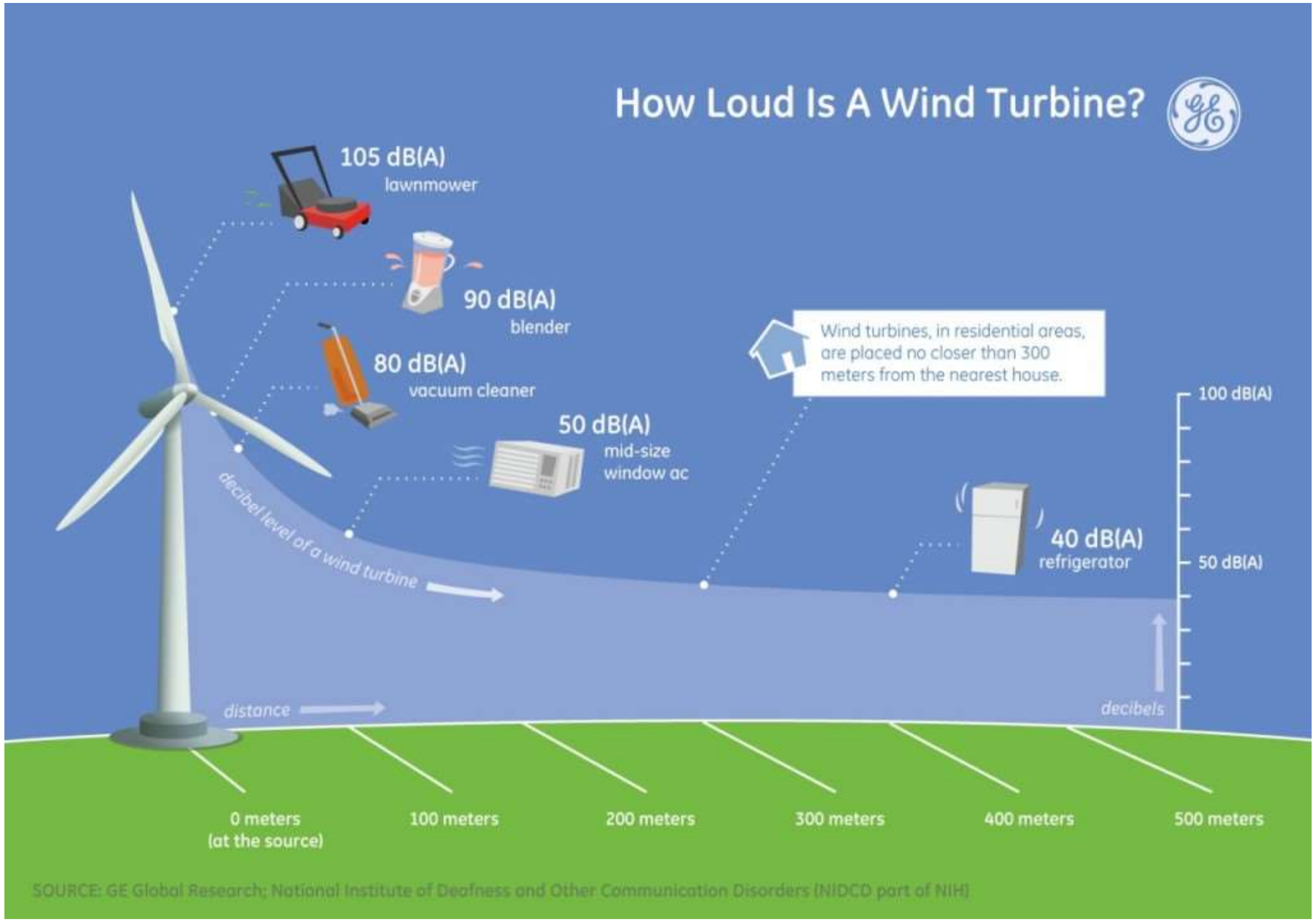
Li *Energies* **5** 5307 2012

Cutler CEEM/EERH Working Paper 2009

Utility in urban environments?



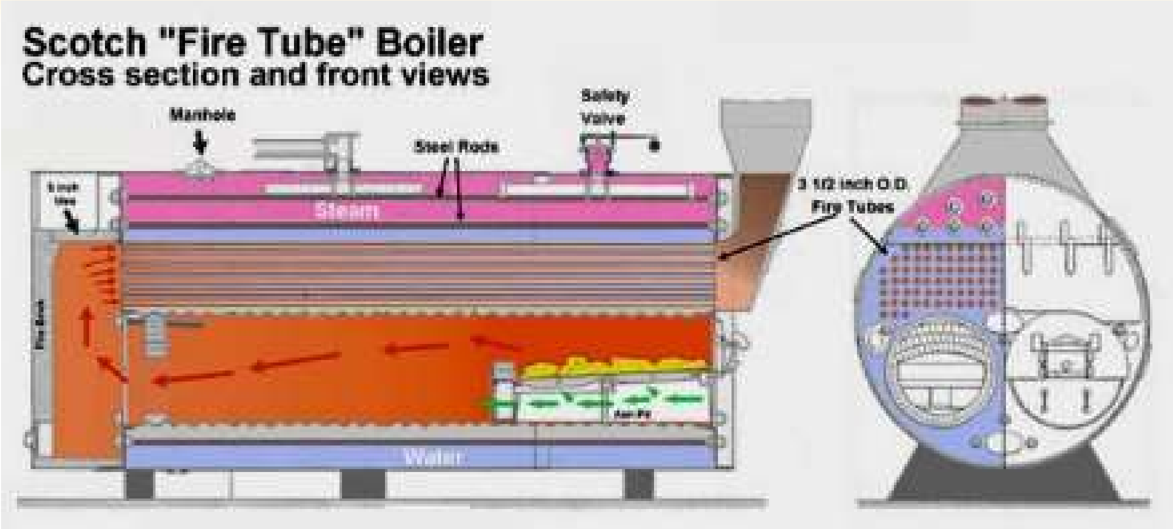
Noise pollution ?

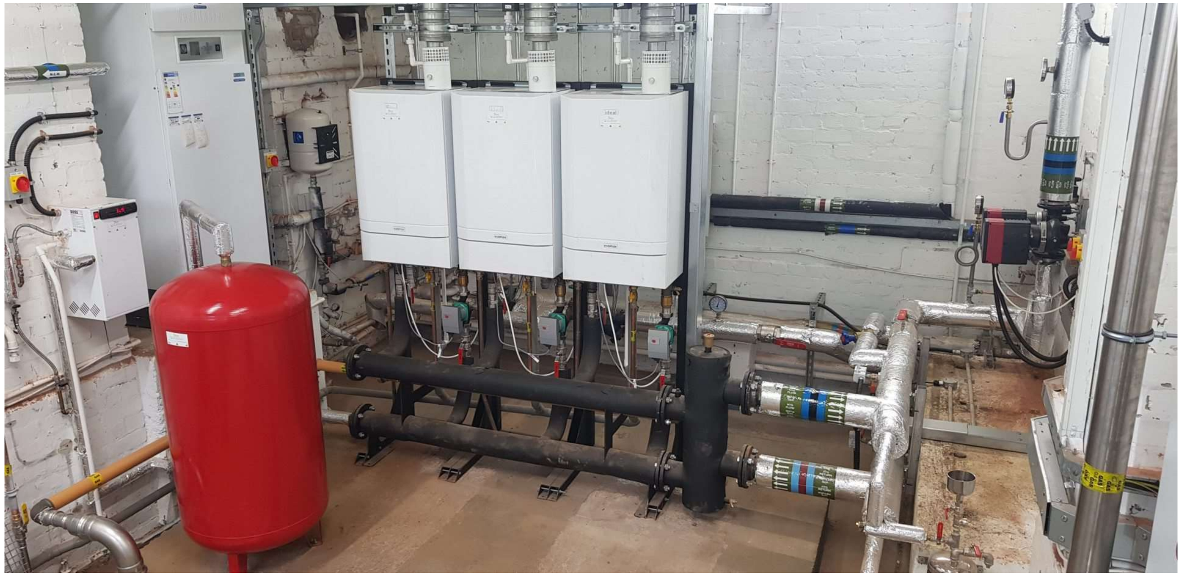


5. ENERGY PRODUCTION SYSTEMS

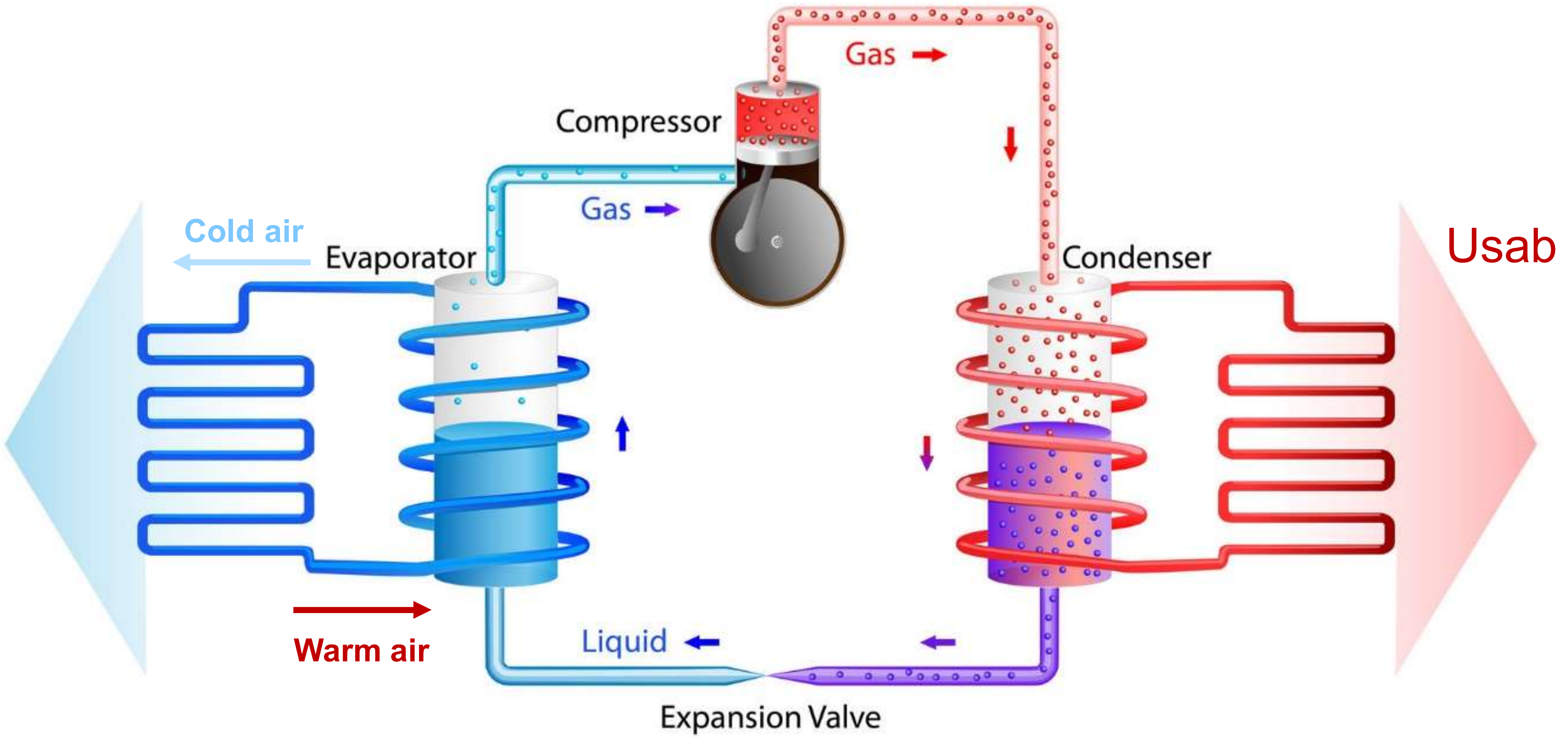
1. Boiler
2. Heat pump
3. Co-generator
4. Chiller
5. Cooling tower

COP = 0.9


Scotch "Fire Tube" Boiler
Cross section and front views
Manhole
Steel Rods
Safety Valve
Steam
3 1/2 inch O.D. Fire Tubes
Water

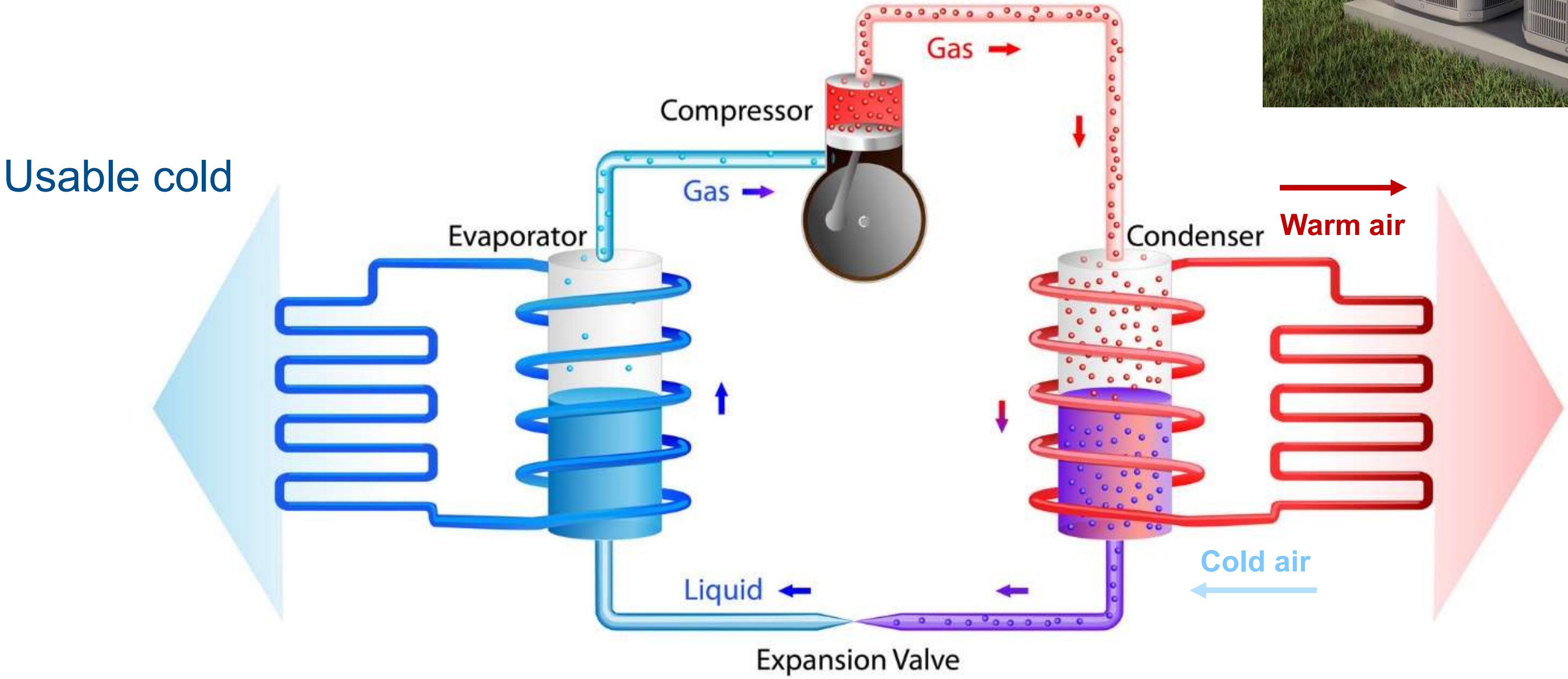


COP = 5
Winter use



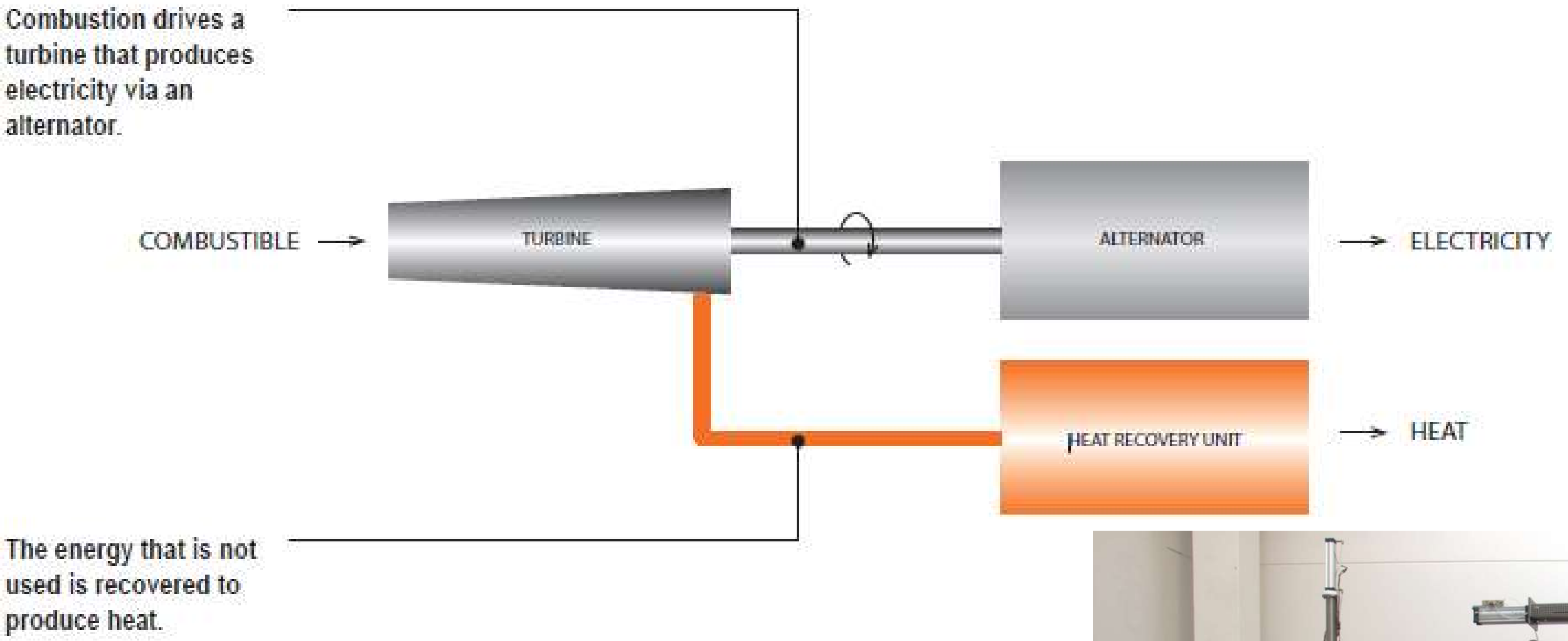
COP = 5
Summer use

© Getty

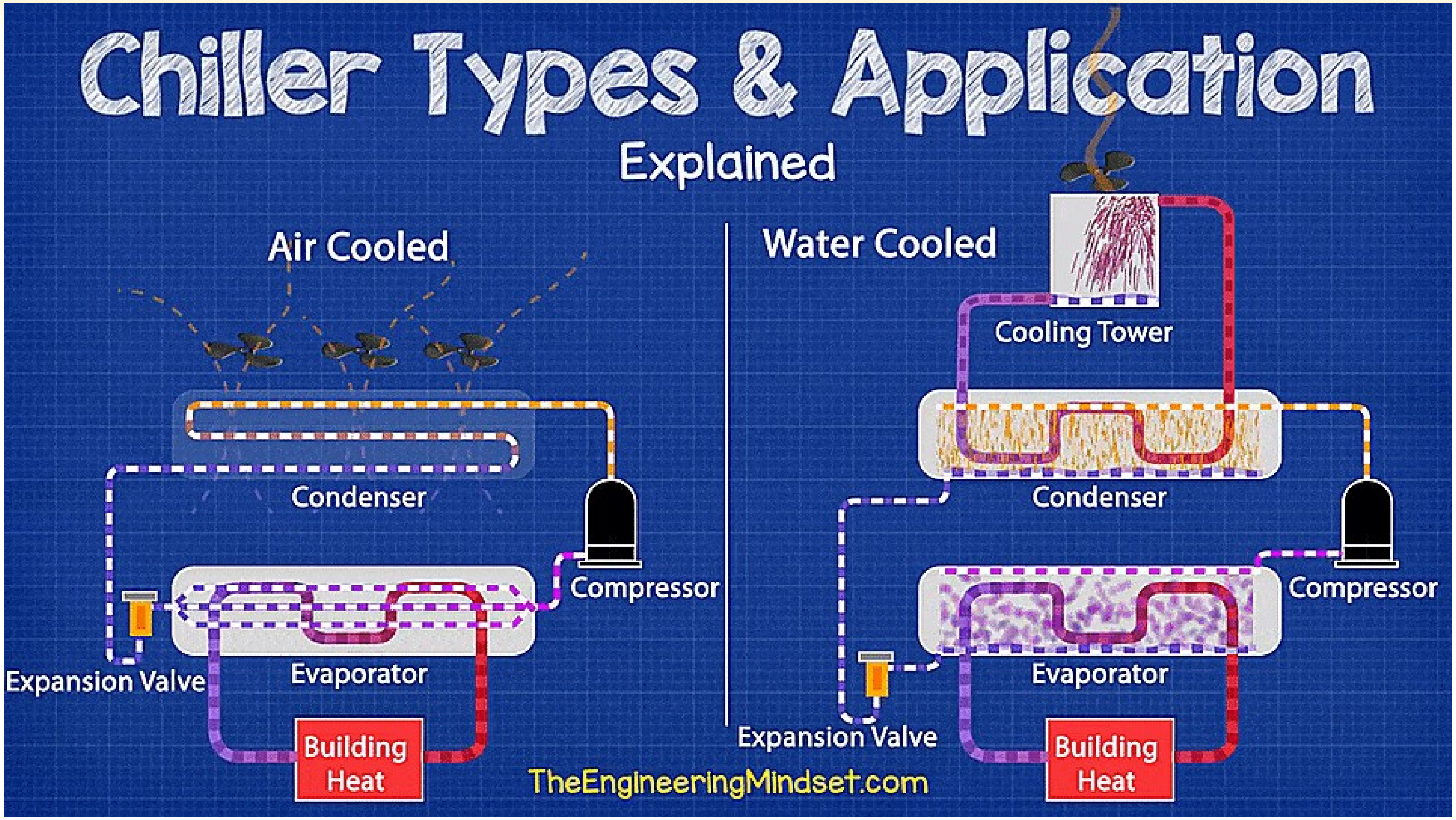


© airteamltd

COP = 0.9

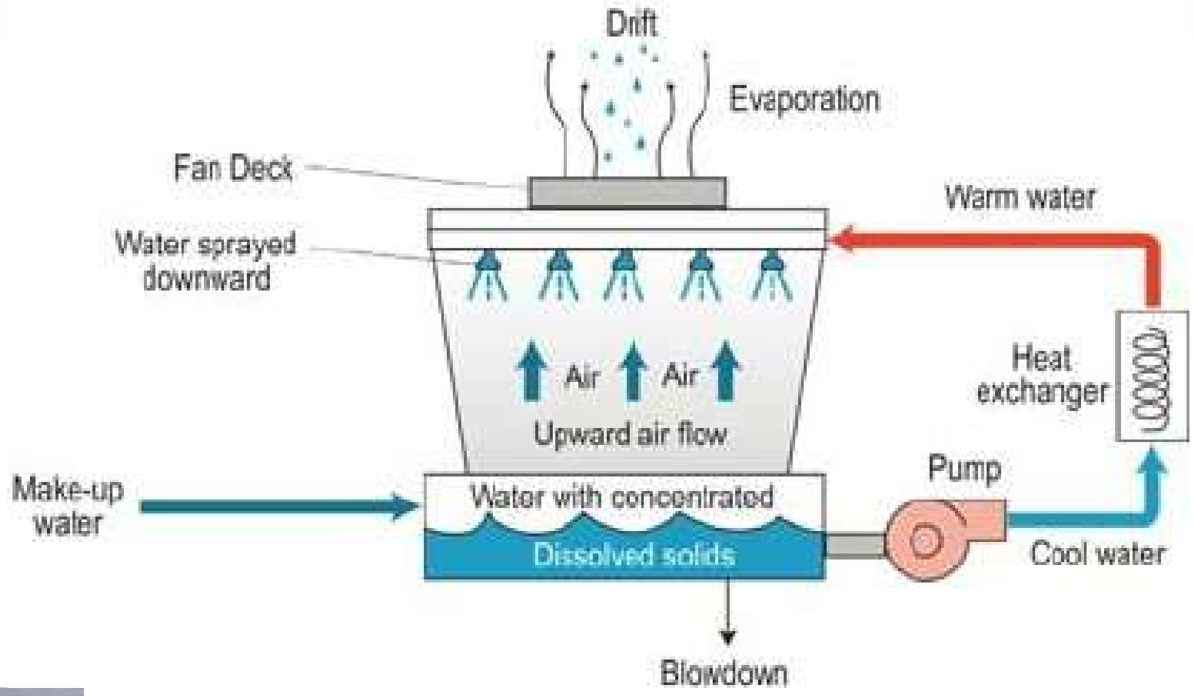

Combustion drives a turbine that produces electricity via an alternator.
COMBUSTIBLE
TURBINE
ALTERNATOR
ELECTRICITY
HEAT RECOVERY UNIT
HEAT
The energy that is not used is recovered to produce heat.

COP = 7



Chiller Types & Application
Explained
Air Cooled
Water Cooled
Cooling Tower
Condenser
Condenser
Compressor
Compressor
Evaporator
Evaporator
Expansion Valve
Expansion Valve
Building Heat
Building Heat
TheEngineeringMindset.com

COP = 12



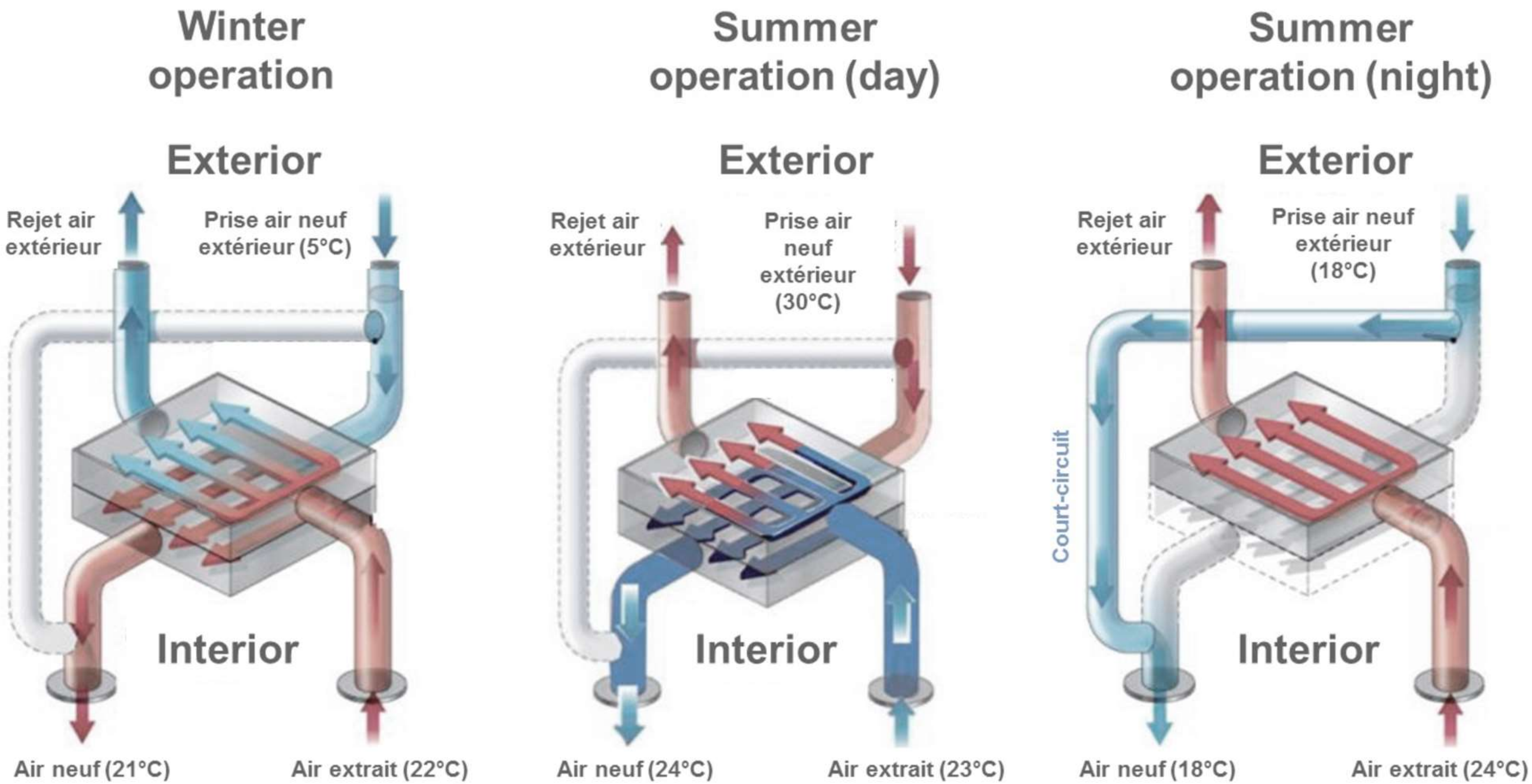
Lakovic *Conf. Mech. Eng.* 2015

© Cooling Tower

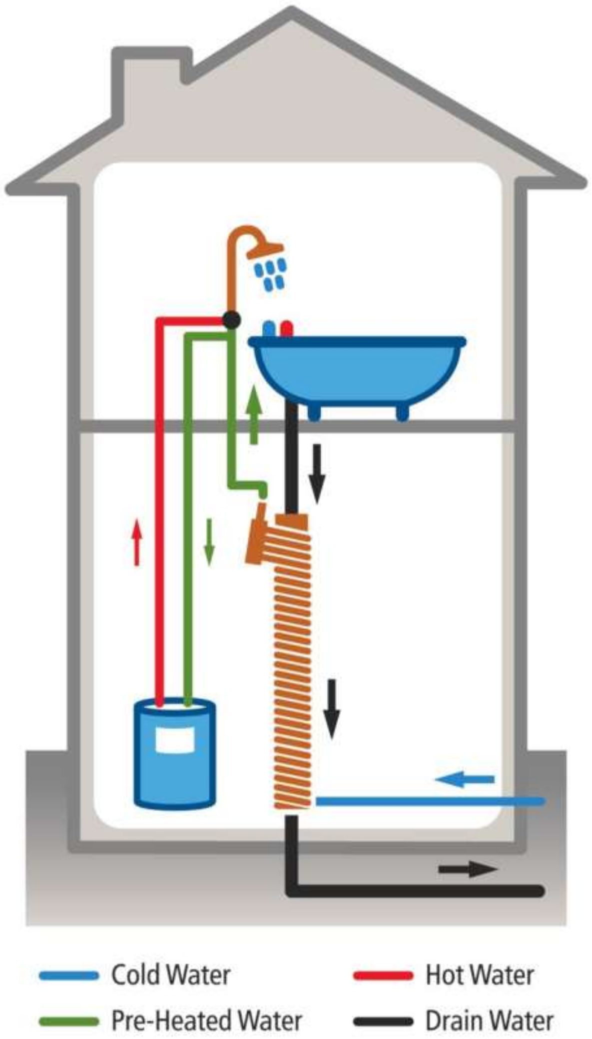
6. ENERGY RECOVERY SYSTEMS

1. Définition
2. Champ et potentiel créé par un dipôle magnétostatique
3. Action mécanique d'un champ externe sur un dipôle

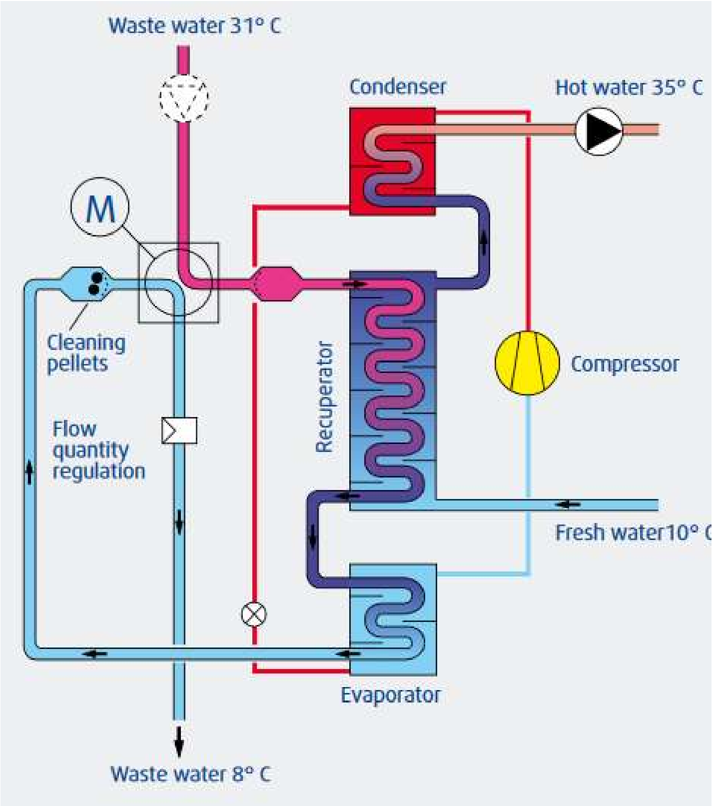
6.1. Dual flow ventilation system



Residential

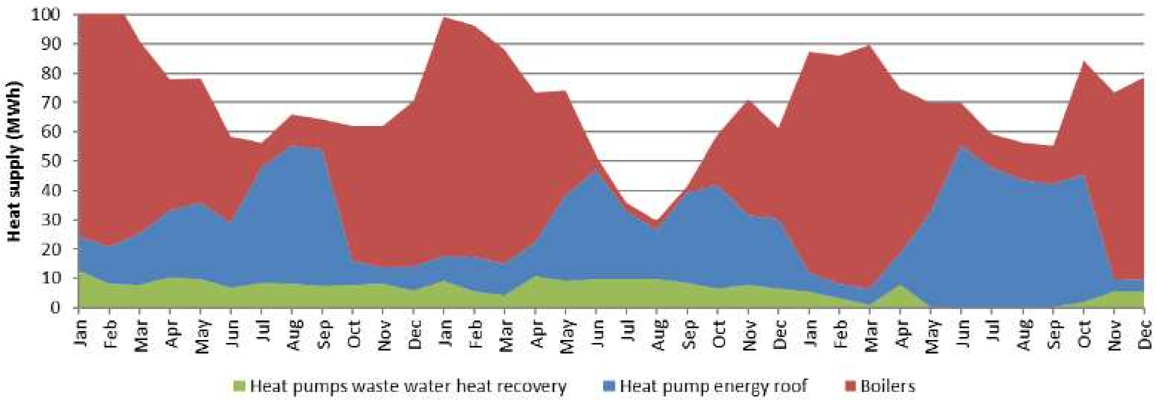


Swimming pools



Non résidentiel : exemple De Nekkerpool à Malines (2014-2016, 1 MW)

- Pompe à chaleur eaux usées des douches (52 kW)
  - Part de 3 %
  - COP moyen mesuré = 6
- Pompe à chaleur eaux usées de la piscine (37 kW)
  - Part de 6 %
  - COP moyen mesuré = 13



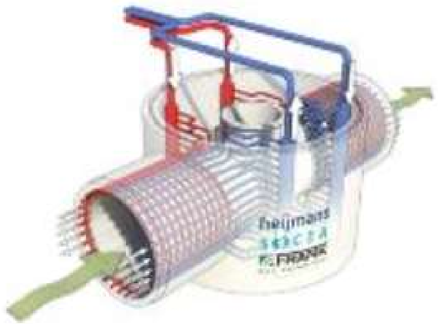
Sewers

Source : Rabtherm

Source : Frank (PKS Thermpipe)

Source : EAWAG

Source : Branderburger Liner



Source : Hydrea Thermpipe