SUSTAINABLE MATERIALS - A COMPLEMENTARY CONCEPT IN THE TRANSITION TOWARDS NEARLY ZERO ENERGY BUILDINGS

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ener2i Energy and Innovation Workshop in ARMENIA, October 02, 2015

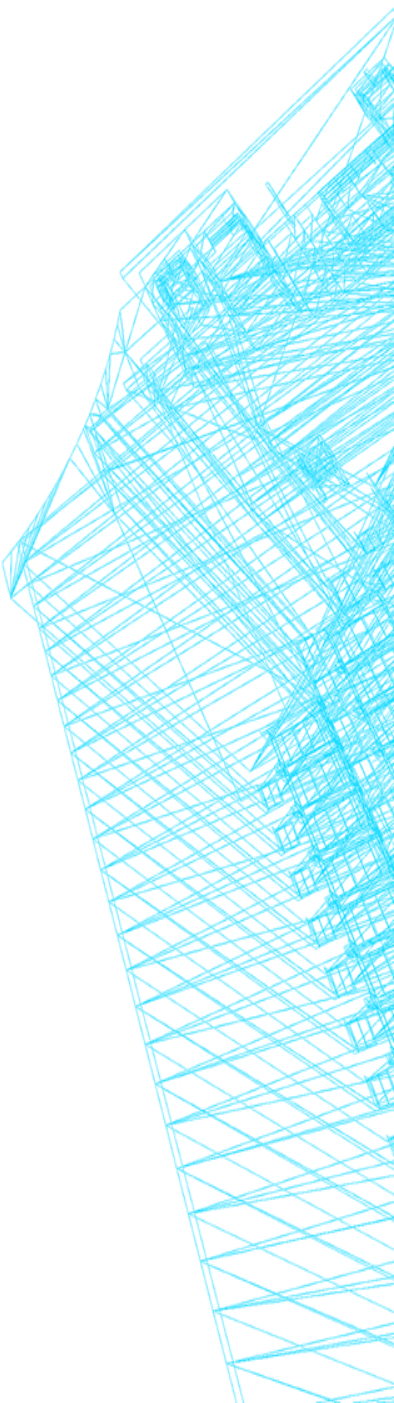
OUTLINE

PART 1. SUSTENABILE BUILT ENVIRONMENT

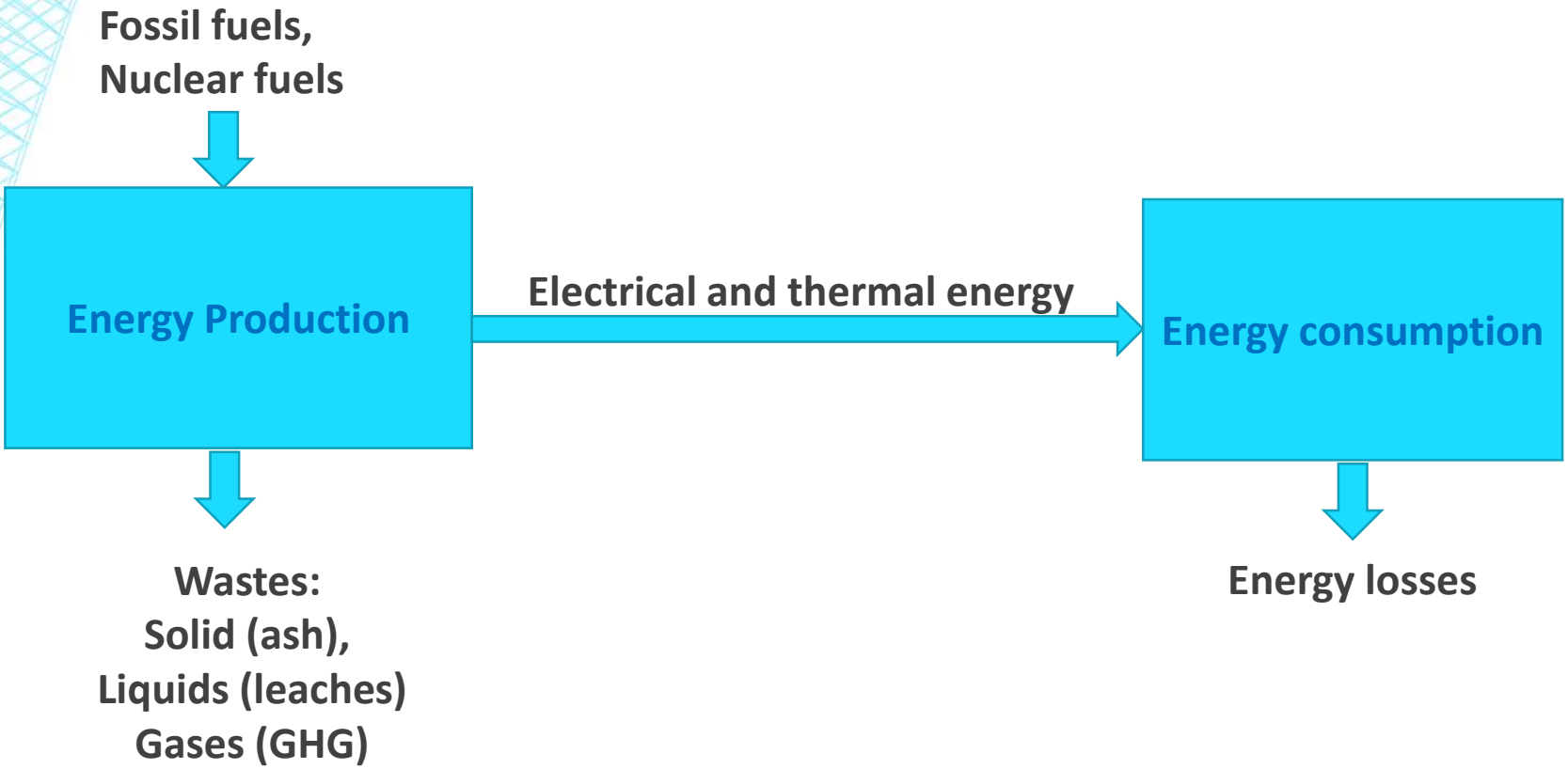
- Energy and sustainable development – a brief history
- Sustainable Energy in the Built Environment, Why?
- Sustainable Buildings

PART 2. SUSTAINABLE COMMUNITIES

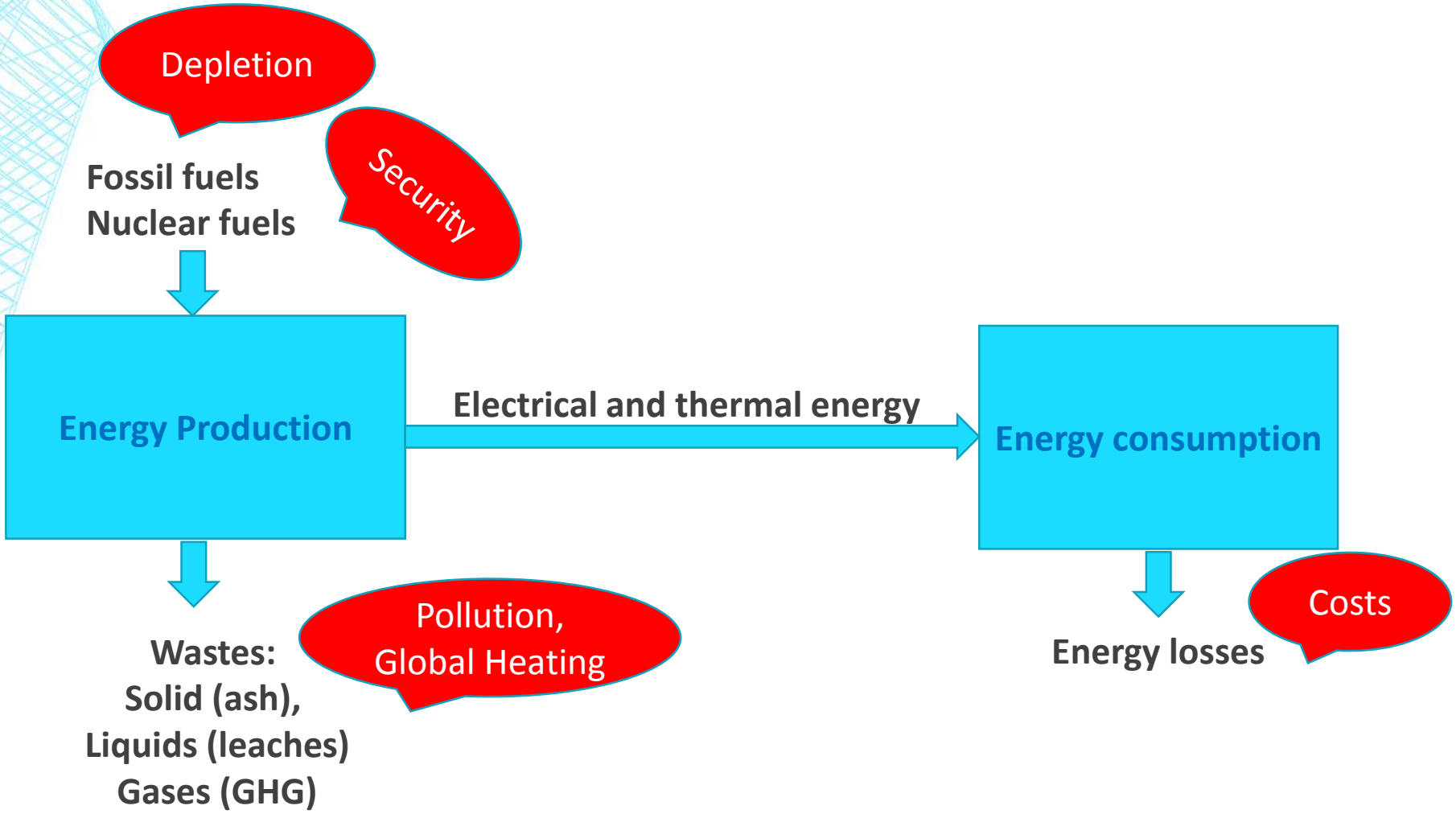
- Sustainable Energy in the Built Environment - Sustainable Communities
- Integrated Energy Mixes for Sustainable Communities
- Case study: The R&D Institute of the Transilvania University of Brasov
- Conclusions



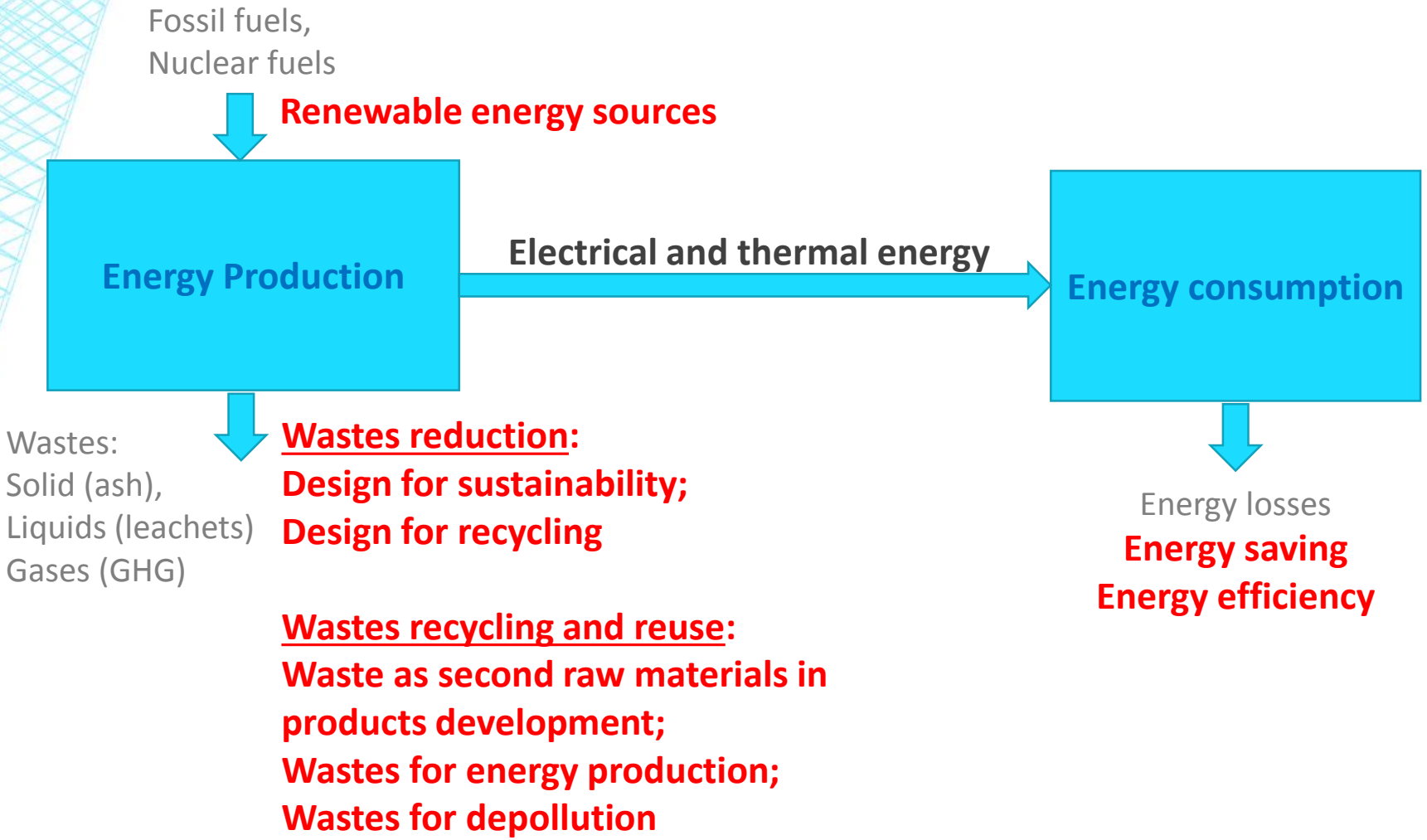
THE ENERGY CYCLE - TODAY



THE ENERGY PROBLEM(S)



THE NEW ENERGY CYCLE – STARTED TODAY FOR TOMORROW



THE NEW ENERGY CYCLE – **SUSTAINABLE ENERGY**

Energy efficiency

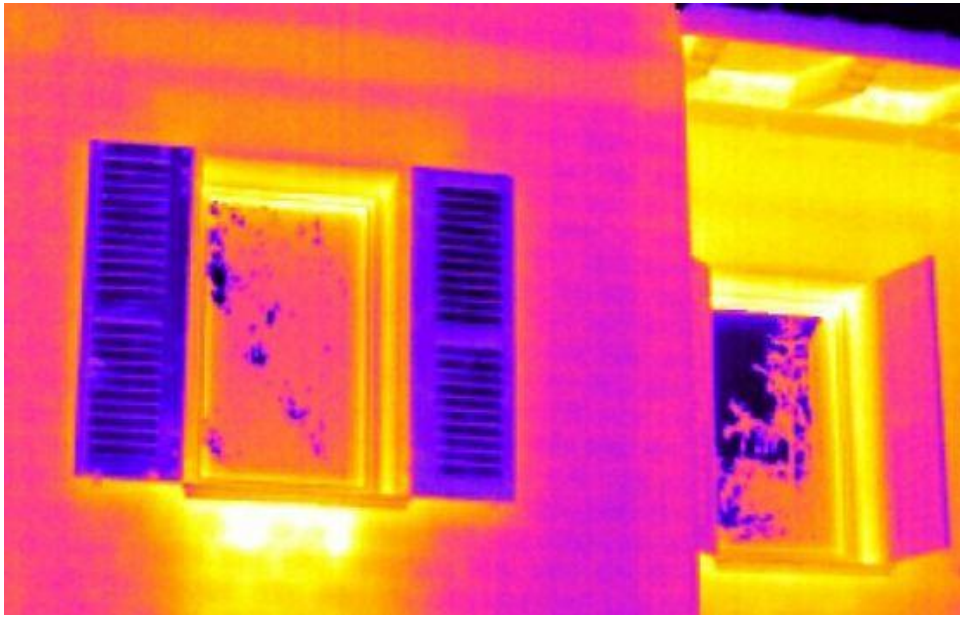
Energy saving

Renewable energy systems

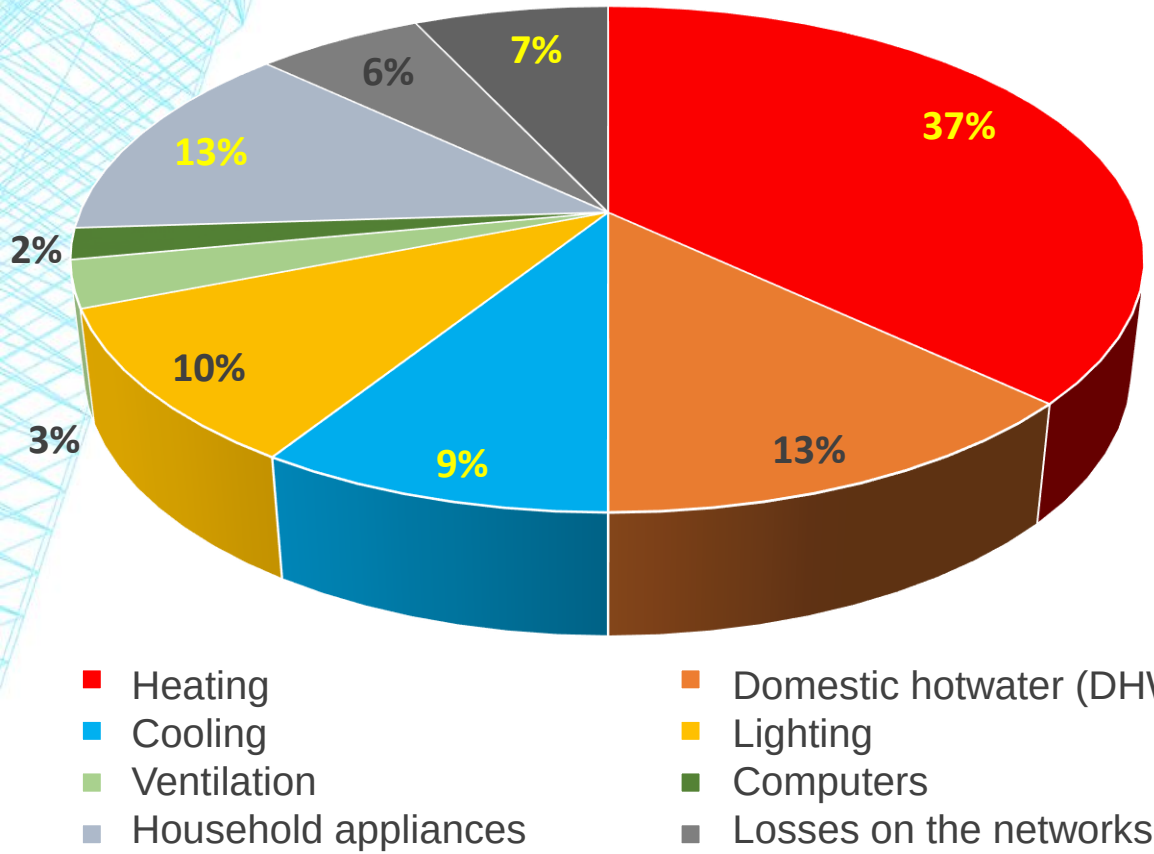
20/20/20 EU Parliament and Council, Directive COM(2008)
The SET Plan

SUSTAINABLE ENERGY IN THE BUILT ENVIRONMENT

Why?



Energy consumption in buildings



Thermal energy (59%)

- Heating: 37%
- DHW: 13%
- Cooling: 9%

Electric energy (35%)

- Lighting: 10%
- Ventilation: 3%
- Computers: 2%
- Household appliances: 13%
- Water pumping: 7%

Losses (6%)

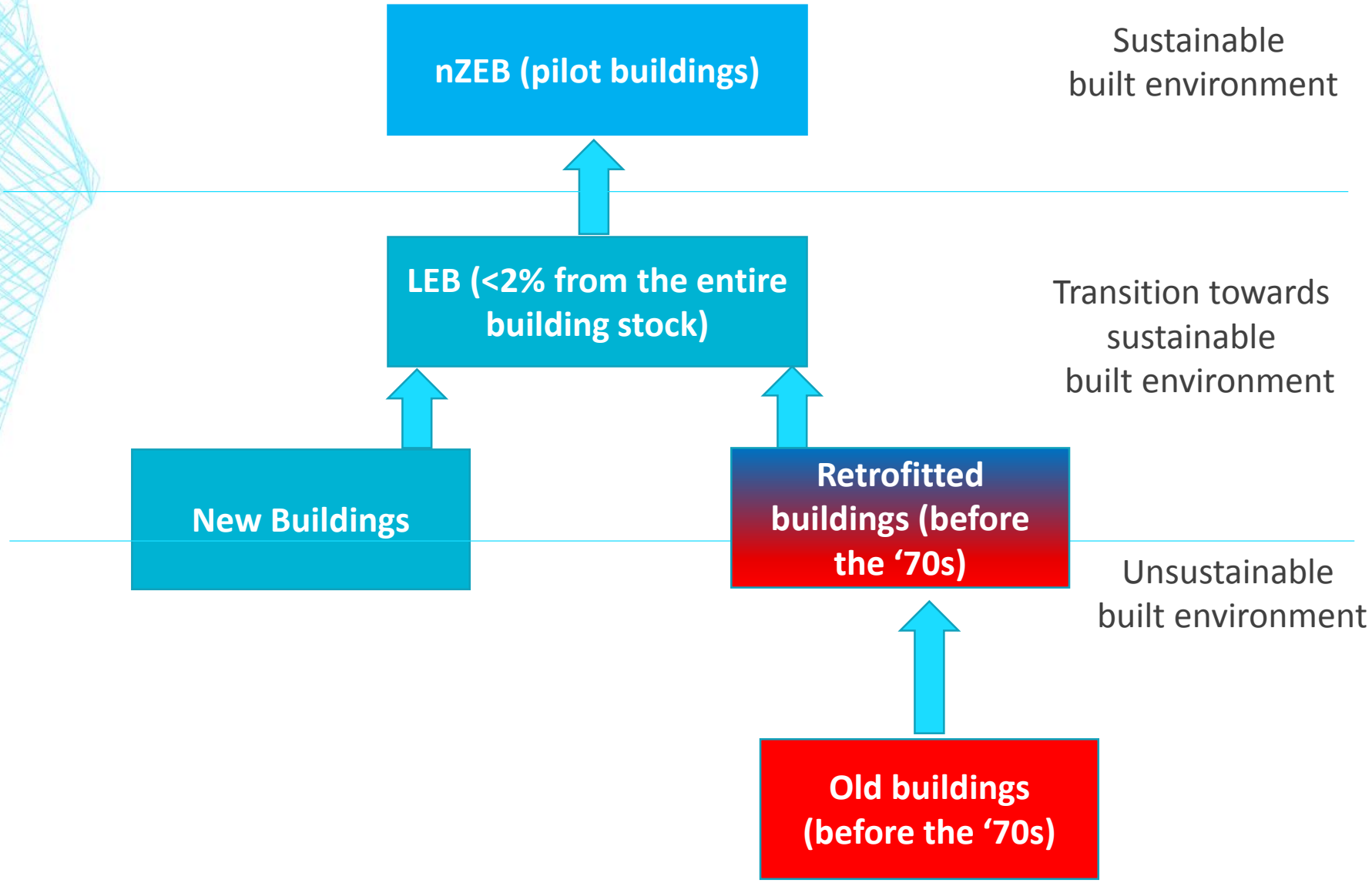
Sustainable built environment

1. Reducing the energy consumption
   - Thermal energy
     - Heating
     - Cooling
     - Domestic hot water
   - Electric energy
     - Lighting
     - Household appliances
     - Multimedia equipment

Low Energy Building (LEB)

2. Using renewable energy sources (clean and affordable)

Nearly Zero Energy Building (nZEB)


nZEB (pilot buildings)
Sustainable built environment
LEB (<2% from the entire building stock)
Transition towards sustainable built environment
New Buildings
Retrofitted buildings (before the ‘70s)
Unsustainable built environment
Old buildings (before the ‘70s)

How to develop a sustainable building?

Electric energy consumption in the built environment

Electric Energy (35%)

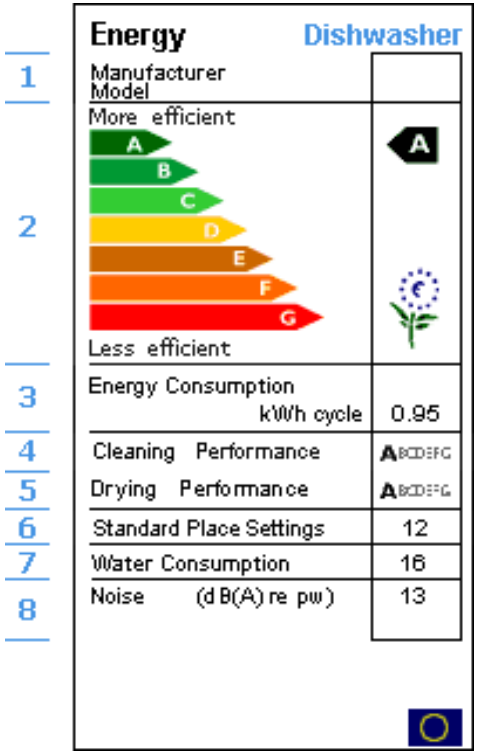
- Lighting: 10%
- Ventilation: 3%
- Computers: 2%
- Household appliances: 13%
- Other: 7%

➔ **1. Maximal use of natural light**

(large glazing, South-orientation, light tubes, etc.)

➔ **2. Energy efficient consumers**

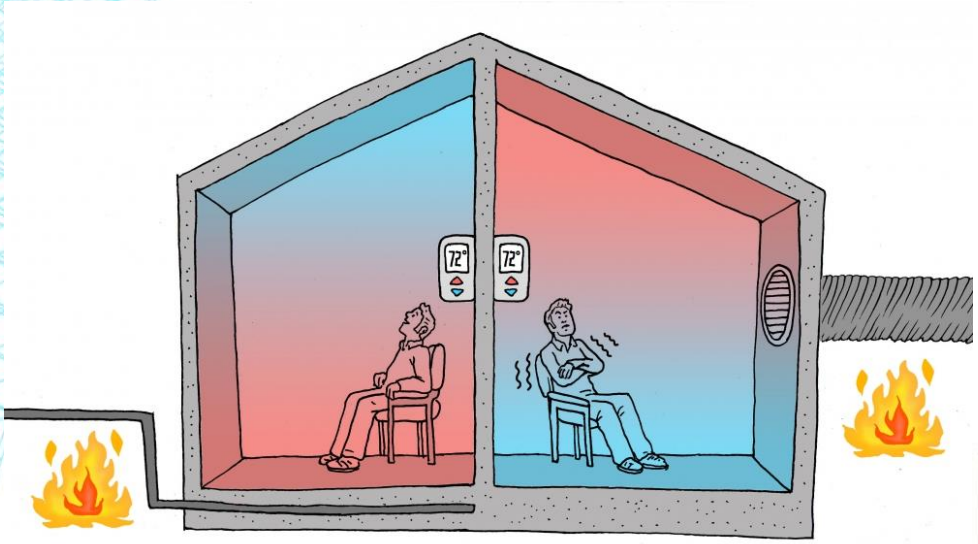
- lighting (LED<fluorescence tubes<W-bulbs)
- green computers, energy efficient equipment (freezers, owens): class A, A+



Energy consumption in buildings

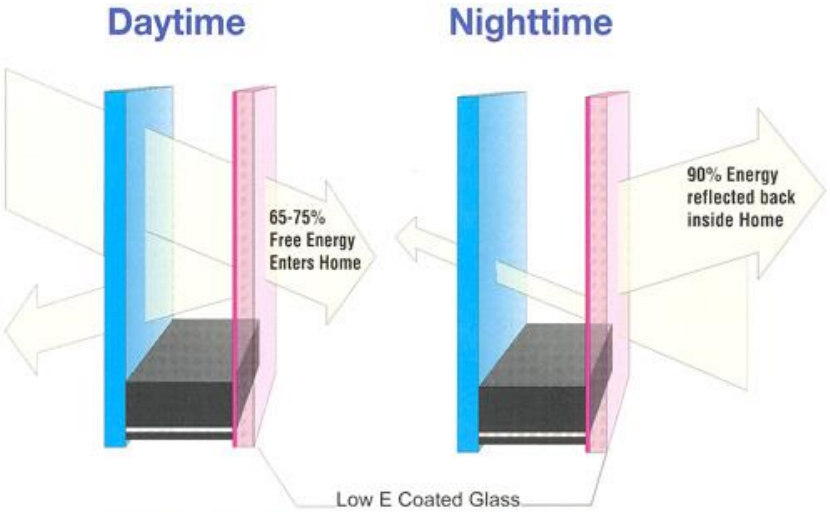
Thermal energy
(59% from the total energy consumption)

- Heating : 37%
- DHW: 13%
- Cooling: 9%



➔ **Reducing the thermal energy demand**

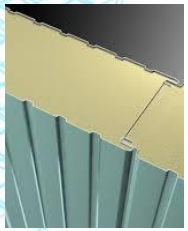
- ➔ Sustainable architectural design
  - ➔ Opaque/glazing ratio; shadowing
  - ➔ Building position towards South
  - ➔ Natural ventilation
- ➔ Sustainable construction
  - ➔ Thermal insulation
  - ➔ Low enthalpy sources (floor, ceilling, walls heating)
  - ➔ Tight fenestration
  - ➔ Spectral selective fenestration (LowE)
- ➔ Building Energy Management Systems (BEMS)
  - ➔ Thermal zoning
  - ➔ Thermosetting
  - ➔ Night cooling



Low E glass reflects heat energy back into your home.

Energy consumption in buildings

➔ **Reducing the thermal energy demand**



Thermally efficient sandwitch opaque structures: metal (steel, Al)/polymer foams (PU, PS) with low thermal conductivity

Controlled optical properties
IR Reflective (in/out) + High VIS Transmittance + Low UV Transmittance: Double/trippled glazing, polymer glazing

Construction materials

High durability materials in the implementation location: concrete, stone

Waterproof:
Polymers, organic/siliconic additives

Energy consumption in buildings

➔ Reducing the thermal energy demand in green buildings

Thermally efficient sandwitch opaque structures: steel/polymer foams (PU, PS) with low thermal conductivity
(polymeric) Wastes, natural materials, glass fibers/wastes

Controlled optical properties
IR Reflective (in/out) + High VIS Transmittance + Low UV Transmittance: Double/trippled glazing, polymer glazing
Multifunctional glazing (self cleaning, electrochromic windows, thermochromic windos)

Construction materials

High durability materials in the implementation location:
concrete, stone
Ceramic wastes

Waterproof:
Polymers, organic/siliconic additives
Traditional construction solutions

Composites
(majoritarly) based on wastes

➔ **Reducing the thermal energy demand <u>in green buildings</u>**

- **Using wastes as second raw materials:**
  - **rubber, plastics, ceramics, concrete, glass (highly energy intensive materials based on critical materials)**
  - **wood waste, crops waste (natural materials)**

- **Increasing the amount of recyclable construction materials embbeded in the building**
  - **recycling and re-use of the construction materials**
  - **design for recycling**

SUSTAINABLE ENERGY IN THE BUILT ENVIRONMENT

The transition towards the sustainable built environment should be:

- **Affordable**
- **Acceptable**

The new concepts must be implemented with the support of the entire community

The result(s)

SUSTAINABLE COMMUNITIES

Sustainable communities

Developing efficient, clean and affordable solutions

- ***Sustainable energy production and consumption***: thermal and electric energy, produced mainly by RES as part of optimized energy mixes.

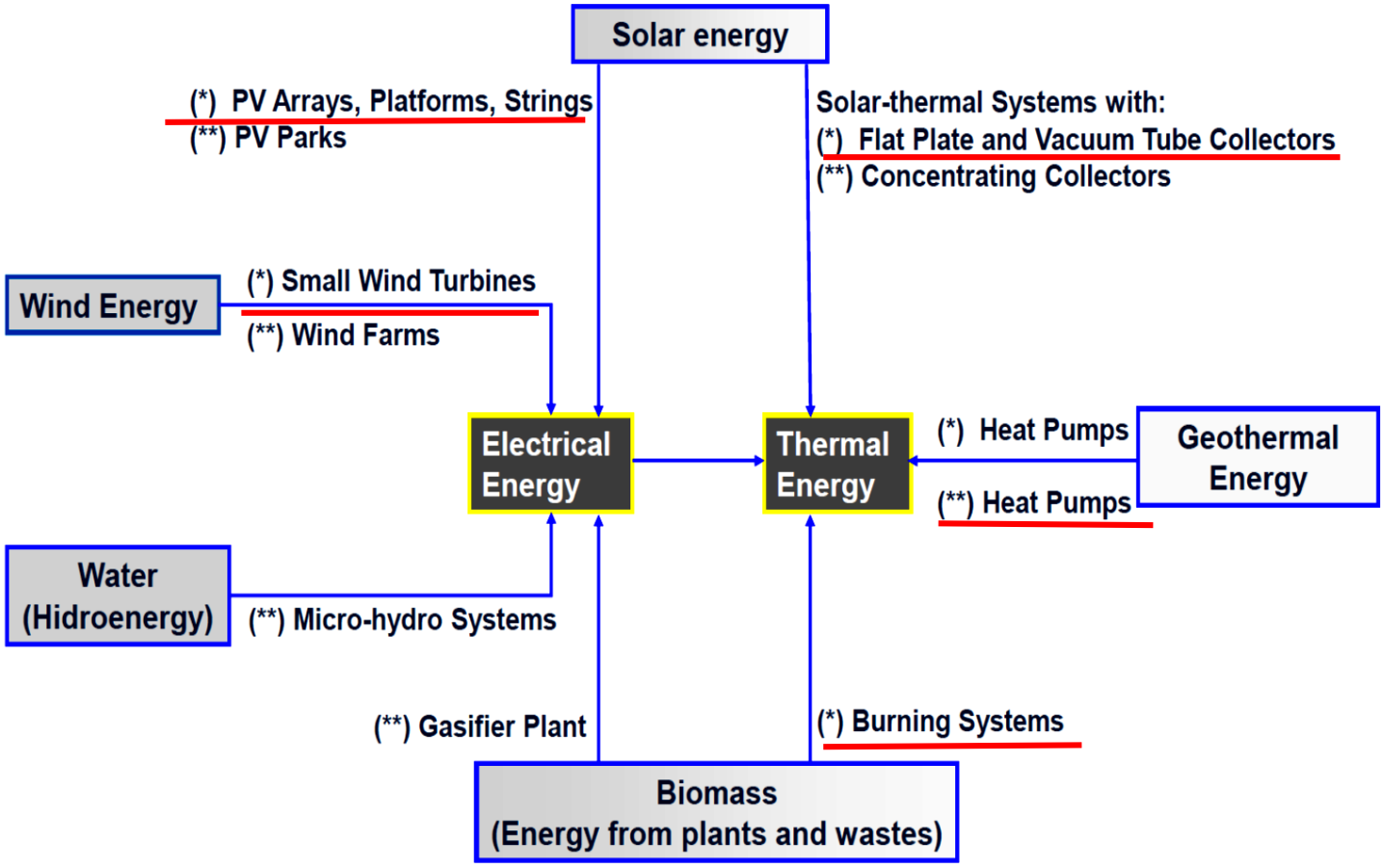
- ***Sustainable built environment***: for efficiently implementing RES-based energy mixes, the energy consumption needs to be significantly lowered, reaching the LEB status. Once reached the LEB status, the coverage of at least 50% of the energy need by using renewable sources will meet the nZEB status.

- ***Sustainable water use***: treatment, delivery, reuse and recycling represents a cycle that should be developed by protecting the natural water resources.

- ***Wastes management***: household waste and the wastes resulted from energy production and/or wastewater treatment need to be processed in a large extent (as for example as energy source) and the rest should be subject of disposal respecting the environmental regulations.

- ***Sustainable transportation*** that requires minimizing the emissions and the use of clean fuels.

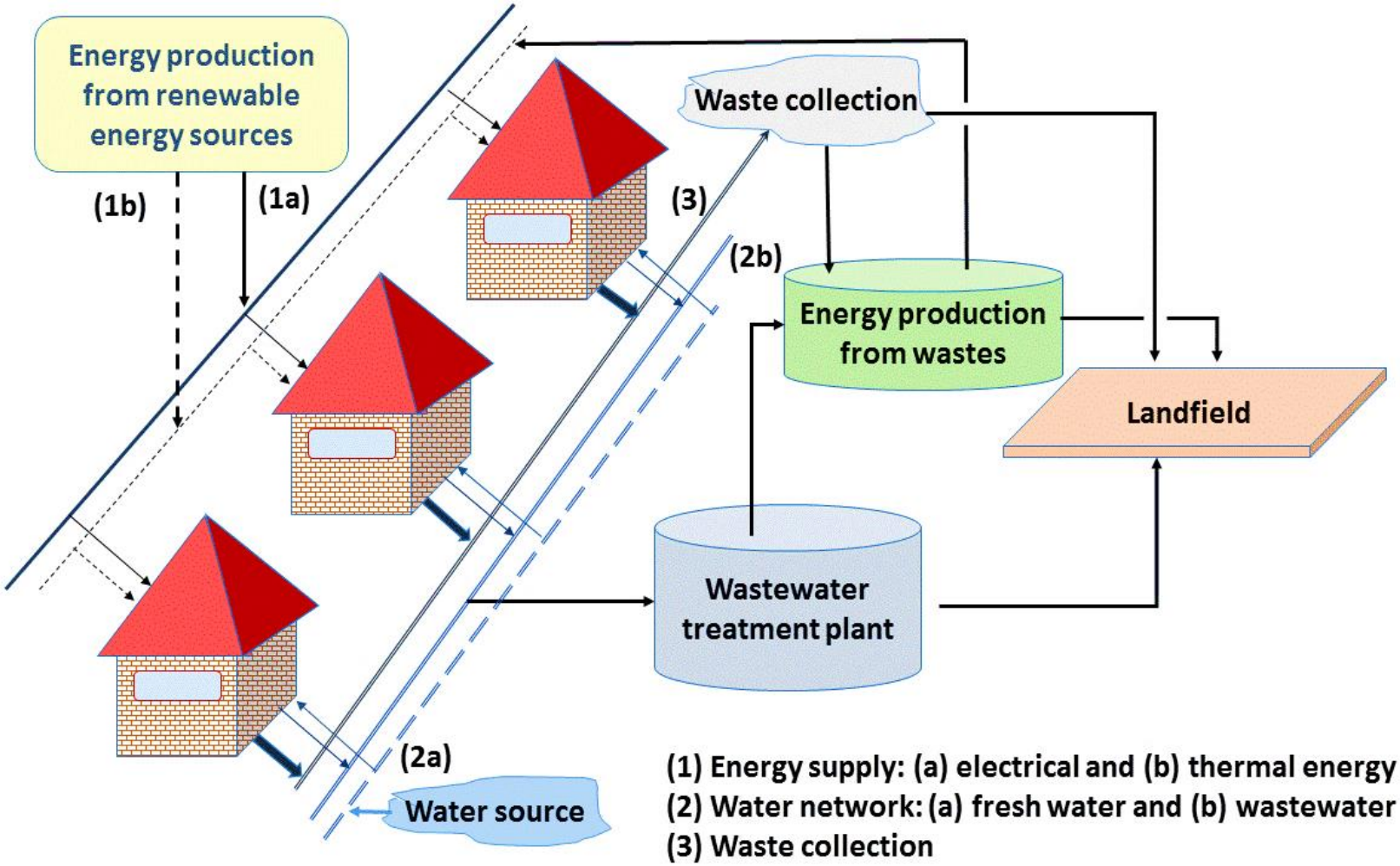
Sustainable communities: meeting the energy demand using renewables



Renewable –based technologies in:
(*) buildings; (**) community

Sustainable communities: meeting the energy demand by using renewables

The community infrastructure is more than the sum of the buildings



(1) Energy supply: (a) electrical and (b) thermal energy networks
(2) Water network: (a) fresh water and (b) wastewater
(3) Waste collection

Sustainable communities:

General Steps

Step 1. Identifying the energy demand

Energy	Common needs in nZEB and in Communities	Specific needs in Sustainable Community
Electric Energy	• Lighting the household • Household appliances • Powering the auxiliary equipment of the RES integrated in the building	• Street lighting • **Wastewater treatment** • Powering the auxiliary equipment of community RES
Thermal Energy	• Domestic hot water • Building heating • Building cooling	• **Wastes processing** • **Wastewater treatment** • Additional heating and drying processes

Sustainable communities:

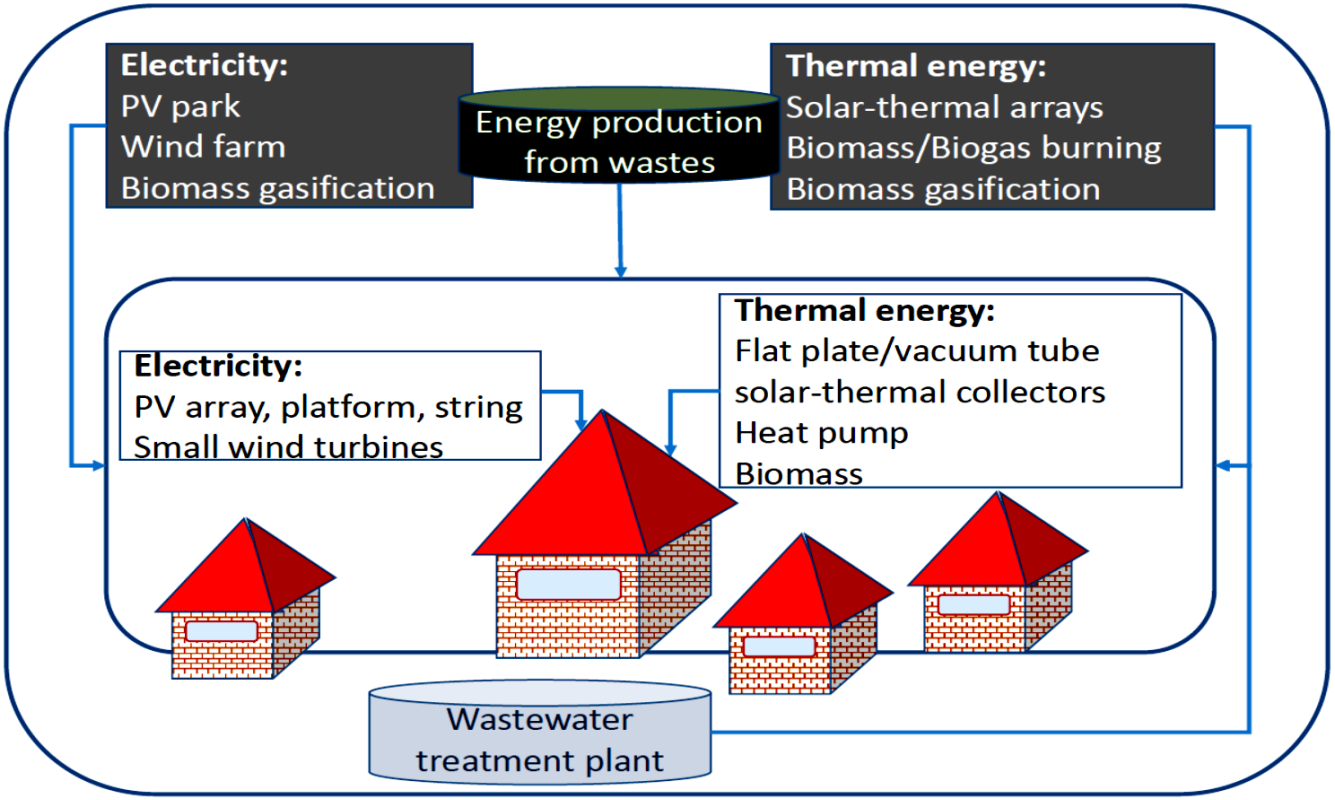
General Steps

Step 2. **Identifying the renewable energies potential**

1. **On site solar energy potential:** yearly, seasonly, peack values, lowest values
2. **On site wind energy potential**: average and peak values
3. **Community small hydro potential**
4. **Biomass availability**

Step 3. Designing the Energy Mixes

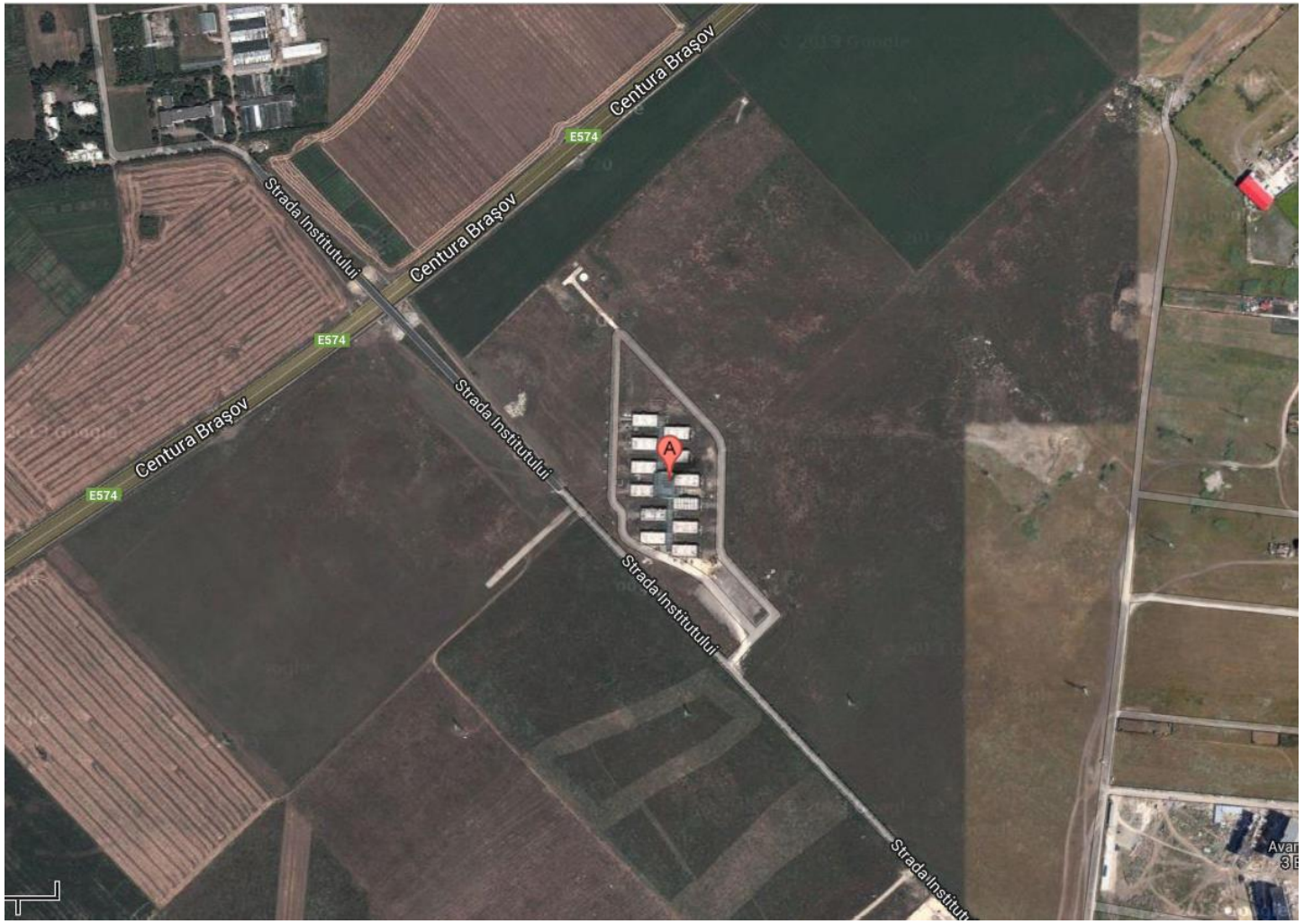
- 3.3. integrating the renewable-based energy mixes installed at:
  - the (low energy) building level
  - community level



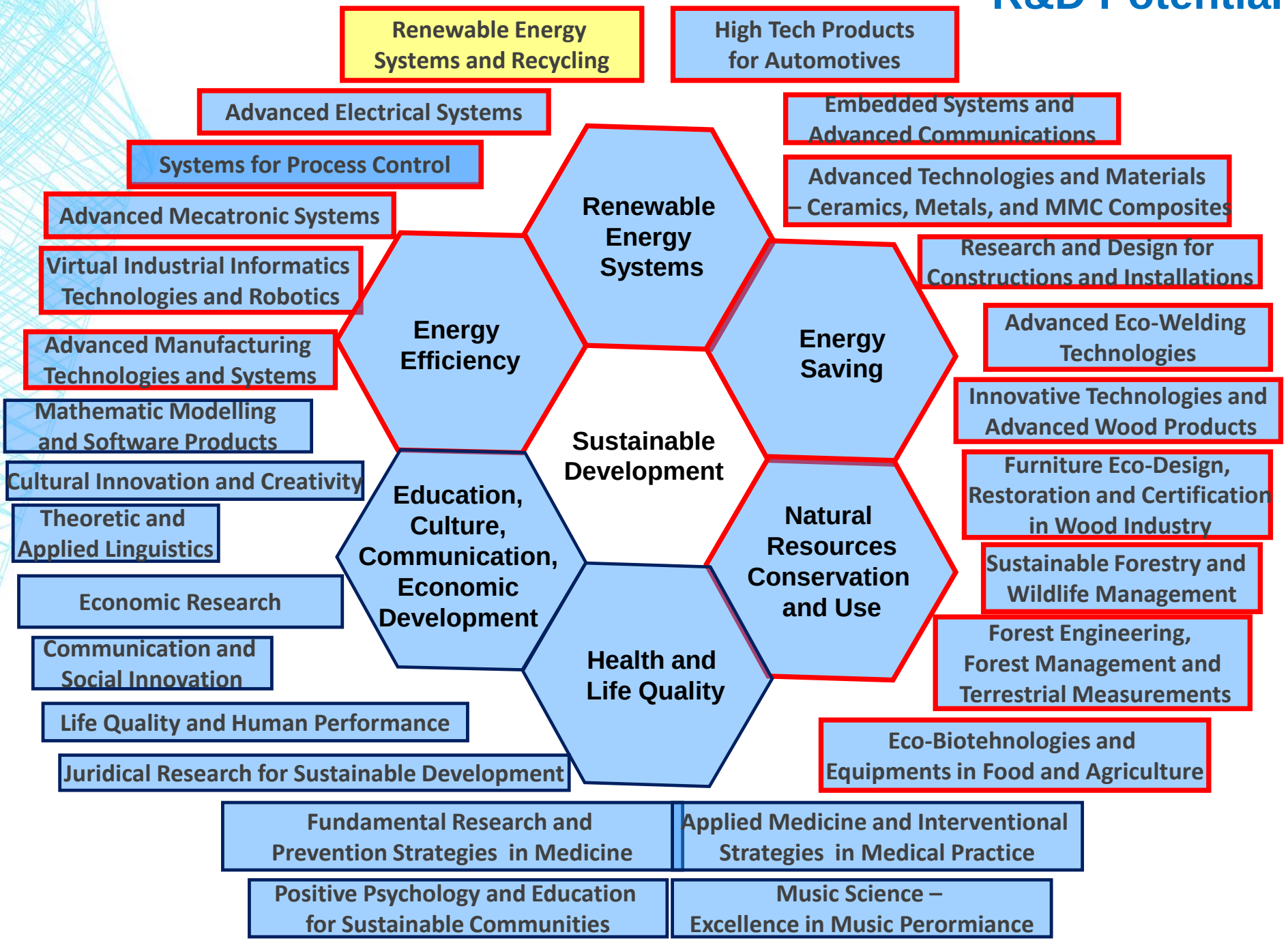
Case study:

The R&D Institute of the Transilvania University of Brasov

The R&D Institute of the Transilvania University of Brasov



R&D Potential



R&D Institute of the Transilvania University

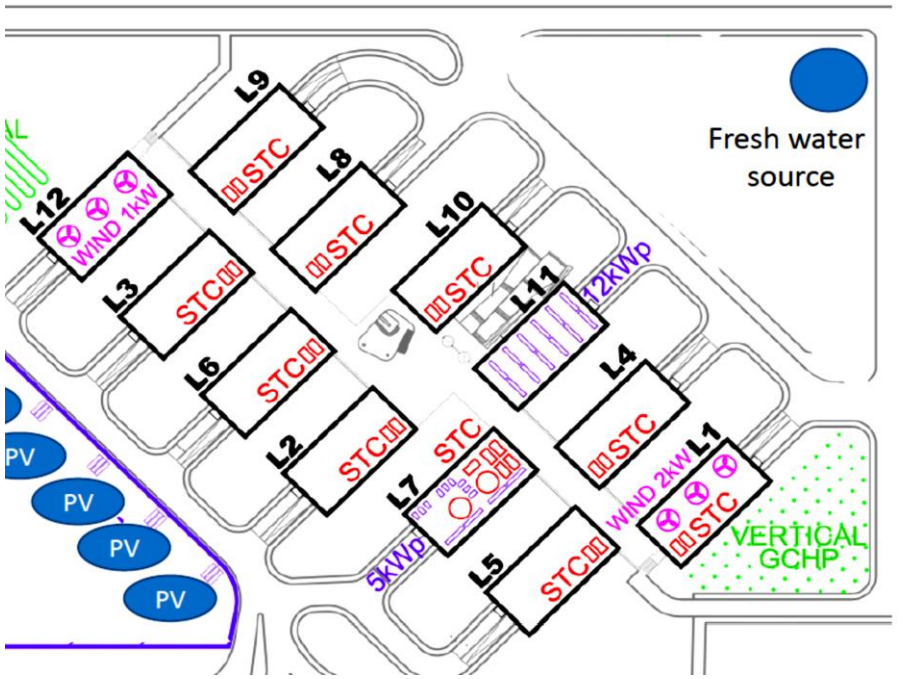
11 Low energy buildings :

Testing rigs towards Sustainable Communities

Transition towards nZEB

- Renewable Energy Systems: solar-thermal collectors (STC), photovoltaics (PV), **heat pumps, small wind farms**
- Monitoring energy consumption
- Green IT systems
- ”Smart grid” systems
- Advanced environmental solutions

Novel solutions designed by the university/RESREC teams



R&D Institute of the Transilvania University

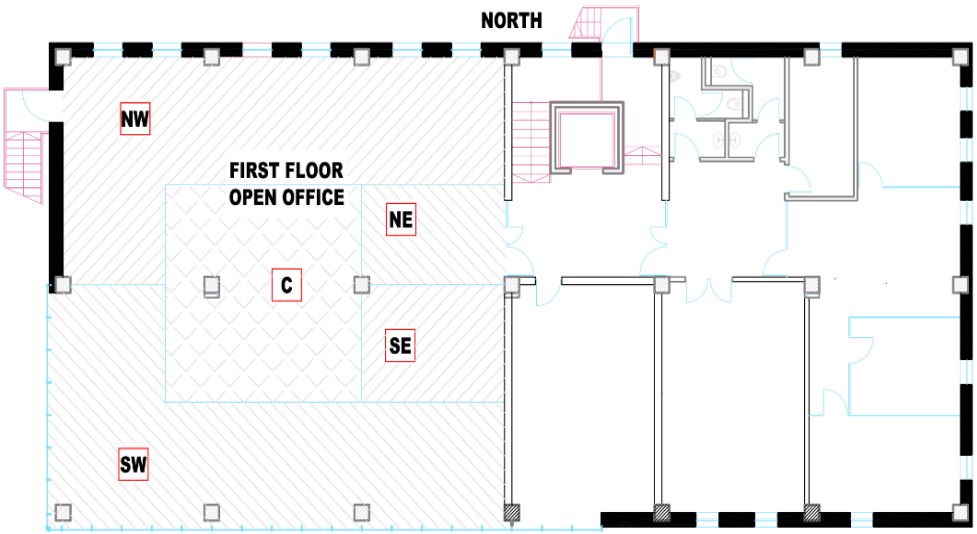
Step 1. Identify the energy demand in the micro-community (The R&D Institute)

Yearly energy demand:

- **Thermal energy** demand 66.69 kWh/m^2:
  - Heating: 57.8 kWh/m^2,
  - Cooling: 5.75 kWh/m^2
  - DHW: 3.14 kWh/m^2

- **Electric energy** demand for lighting and other powered appliances (except the specific laboratory equipment):
  - 13224 kWh, (12.6% from the total energy demand)

Total: 79 kWh/m^2/year → **LEB**



Visa I., at al. Energ. Build., 2014

R&D Institute of the Transilvania University

Step 2. Identifying the renewable energy potential in the micro-community

Solar energy potential: 1200 kWh/m^2/year

- winter months: 20…45 kWh/m^2/month in November…February
- summer months: 150…250 kWh/m^2/month in May… August.

***Wind energy*:**

- wind speeds less than 2.5 m/s (over 75% of the year)
- values reaching 9 m/s at 15m height.

Micro-hydros: no water flows.

Geothermal energy: good potential

***Biomass*:**

- Restrictions due to storage facilities for wood (waste)

R&D Institute of the Transilvania University

Step 3. Designing the energy mix

Electricity production:

- **Energy mix**: PVs + wind turbines with very low cut-in speed.
- **Using the grid** as storage system and backup source.

Thermal energy production:

- **Energy mix**: Solar-thermal systems + ground coupled heat pumps.
- **Backup source**: gas.

Optimization: Assessing the infield output of the RES

One "testing building":
The R&D Centre Renewable Energy Systems and Recycling

Step 3. Designing the energy mix. Optimization on the RESREC location

Building L7:

- tracked PV modules (7kWp);
- trough and flat plate tracked solar-thermal collectors
- PVT (mono-crystalline Si)

Building L11:

PV string platform (12 kWp)

Ground: 5 PV platforms

Step 3. Designing the energy mix. Adapting PVs to the implementation location

Visa I., et al., J. Renew. Sust. Energ., 2014

Relative efficiency loss ($\Delta\eta_{PV}$) for different fixed tilt PV modules (reference: nominal efficiency)

PV module	Si-mon	Si-poly	Si-a	CIS (CuInS2)
$\Delta\eta_{PV}$ in April	-40%	-35%	-60%	-20%
$\Delta\eta_{PV}$ in September	-70%	-45%	-60%	-33%

Step 3. Designing the energy mix for one Laboratory Building L7 (RESREC)

Prerequisites:

- Covering the thermal energy demand (heating cooling and domestic hot water);
- Minimizing the electric energy needed for powering the heat pump;
- Minimizing overheating the flat plate collectors.

The optimal mix (net zero energy building):

Thermal energy:

80% heat pump (21.2 kW, COP=4.5) functioning in direct (heating)
and reverse (cooling) modes
20% solar-thermal system.

Electric energy (lighting, office appliances, powering the heat pump and solar-thermal system), 31825 kWh/year:

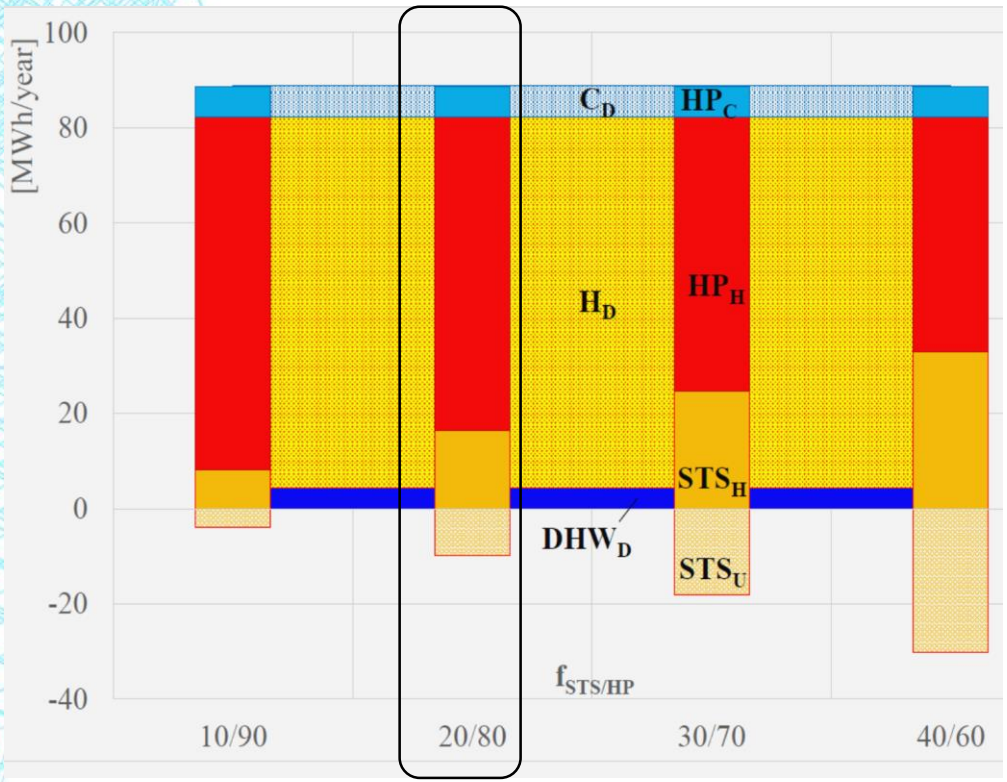
- mono-axial tracked PV array of 35.8 kW_p

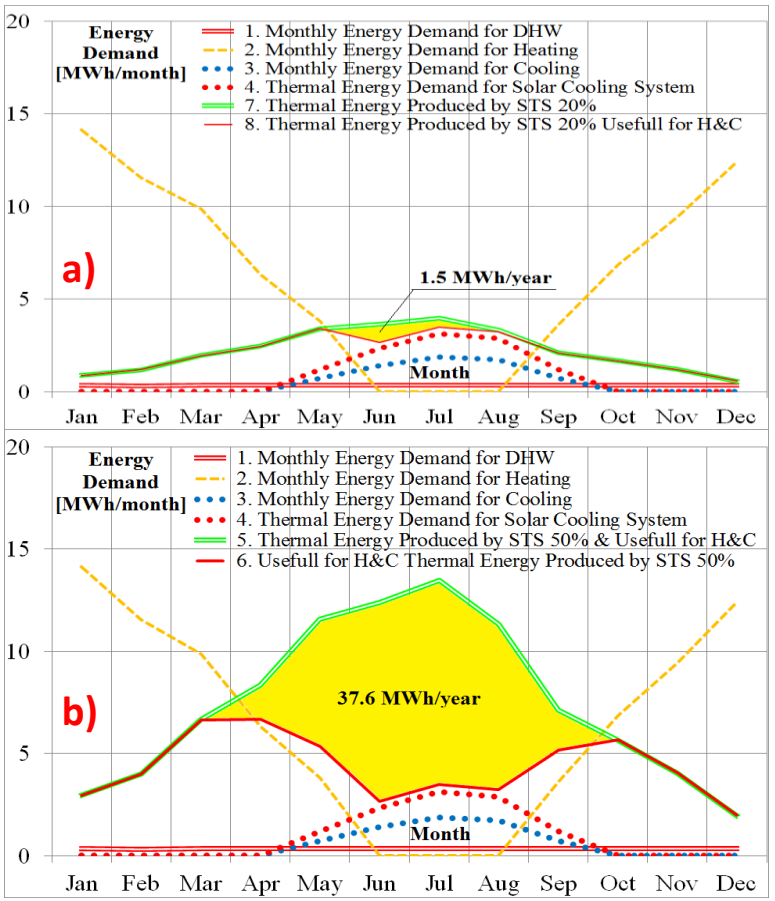
PV surface: 238 m^2 ➔ implementation surface: 1000 m^2

Note: The PV surface is not available on the building (rooftop area: 450m^2) and does not represent a feasible alternative when replicating the energy mix towards other micro-communities ➔ 50% of the Electric Energy could be covered by RES

Step 3. Implementing the thermal renewable energy mix

x% Heat Pump (HP) / (100 – x) % Solar-thermal Systems





Energy demand of the building

DHW_D: for domestic hot water

H_D: heating energy demand

C_D: cooling energy demand

Energy provided by the RES components

HP_C: energy for cooling from the heat pump

HP_H: energy for heating from the heat pump

STS_H: energy for heating and for domestic hot water from STS

STS_U: exceeding heat from the STS

Excess energy provided by STS in:

a) 20% STS + 80% HP

b) 50% STS + 50% HP

Conclusions

- The development of sustainable communities should be done step-wise;
- Accurate input data (energy demand, renewable energy potential) must be evaluated based on the specific features of the community and on the on-site climatic conditions;
- Renewables – based energy mixes should be preliminary designed following two schemes:
  - (i) to be installed on the buildings;
  - (ii) to be installed at community level;
  - The two schemes need to be integrated, aiming at synergy in the detailed design of the energy mix for the entire community.
- Pilot solutions should be developed and tested before large scale replication.
- The choice for developing LEB and nZEB buildings should consider the initial investment and the payback time.
- Careful and specialized design should be employed for giving use of all the local resources, for avoiding over- or under-sizeing.

Conclusions

- The R&D Institute of the Transilvania University of Brasov represents a **micro-community that can reach full energy autonomy by using RES mixes** based on heat pumps, solar-thermal arrays, PV tracked platforms and small wind turbine farms.
- The investment cost for the 11 LEB is of about **860 EUR/sqm**.
- Tailored solutions can be developed (by request) for beneficiaries (communities and house owners).
- Solutions are developed for increasing the architectural acceptance – **solar facades**.

Thank you!

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