UNIVERSITÀ DEGLI STUDI DI TRIESTE

Regulatory Framework and Building Energy Design

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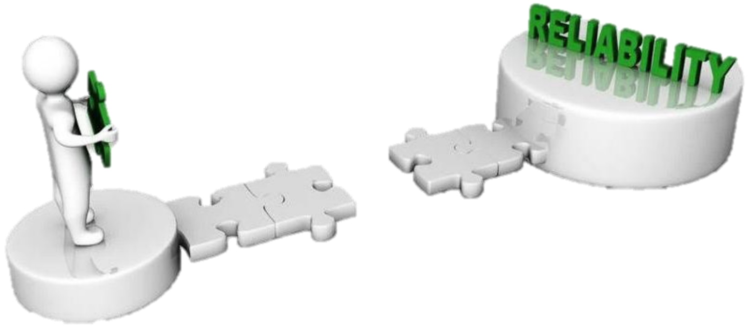
Climate change impact on heating and cooling energy consumption

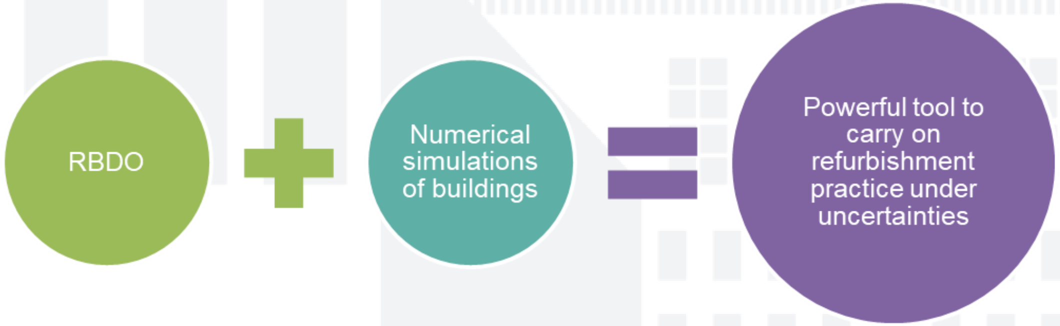
Climate change impact on buildings – an example of a refurbishment optimization

In the common practice energy simulations are carried on by considering all parameters as deterministic, however in reality this is not correct

- Energy price
- Investment cost
- Material characteristics
- Internal heat gains
- Climate



Reliability is intended as the probability that a certain design will not fail to meet a criterion or performance



Reliability Based Design Optimization (RBDO) searches an optimum design with allowance of a specific risk and target reliability level, accounting for the various sources of uncertainty

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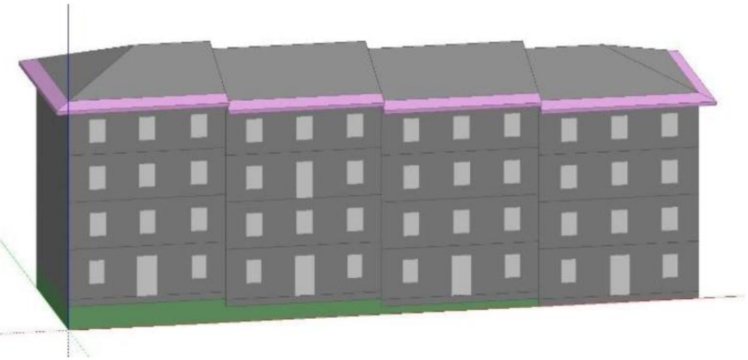
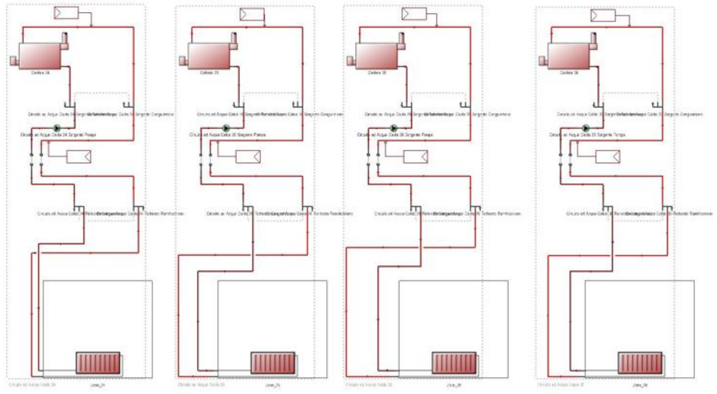
Social housing building located in Trieste, with four centralized heating plants and no cooling systems



Window type	U_g[W/(m²K)]	SHGC [-]	Cost [€] Small	Cost [€] Large
Base	5.7	0.870	-	-
Type 0	1.4	0.660	226.2	417.8
Type 1	1.2	0.425	227.3	423.2
Type 2	0.8	0.398	244.3	500.6



Opaque constr.	U_{base} [W/(m²K)]	U_{ref} [W/(m²K)]		t_{ins} [cm]		$Cost_{ins}$ [€/m²]		λ_{ins} [W/(m K)]	ρ_{ins} [kg/m³]	c_{ins} [J/(kg K)]
		max	*min*	*min*	*max*	*min*	*max*			
Wall	1.55	0.822	0.215	2	14	9.24	40.60	0.035	25	1,400
Ceiling	14.71	1.565	0.173	2	25	4.93	39.61	0.036	140	1,030
Roof	5.88	1.350	0.170	2	20	13.07	71.15	0.035	25	1,400
Floor	2.89	1.090	0.165	2	20	9.42	53.49	0.035	35	1,400

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STOCHASTIC PARAMETERS

Energy price trend

Analysis of past trends from energy information administration led to a normal distribution of the energy price trend:

- Mean value $\overline{r_e} = 1.59\ \%$
- Standard deviation $\sigma = 1.4\ \%$
- Constraint $r_e > -1.0\ \%$

Investment costs

Investment cost is computed using regional prices

Additional optimization with a uniform distribution of investment costs with a range of ±10 % is carried on

ECONOMIC INDEXES

Parameter	Value	Unit	Source
Gas (*)	0,899	€/m³	EUROSTAT
Electricity (*)	0,255	€/kWh	EUROSTAT
Inflation rate (r_i) (**)	1,173	%	Worldwide Inflation Data; www.inflation.eu
Discount rate (r_n)	4,090	%	Bank of Italy
Energy price trend (r_e)	1,59 (s.d. 1,40)	%	Energy Information Administration

(*) Mean last 10 years prices for household consumers all taxes and levies included

(**) Mean last 10 years

OPTIMIZATION SETTINGS

- Non-dominated Sorting Genetic Algorithm (NSGA II)
- Initial population: 24
- Generations: 40
- Total solutions: 960
- Six optimization runs (one per climatic set)
- 30 years optimizations divided in two periods: 2021-2035 and 2036 - 2050

OPTIMIZATION TARGETS

Minimization of Primary Energy (PE) consumption:

Maximization of NPV 10° percentile

Minimization of summer discomfort hours (N28):

- Hours in which inside temperature is greater than 28 °C

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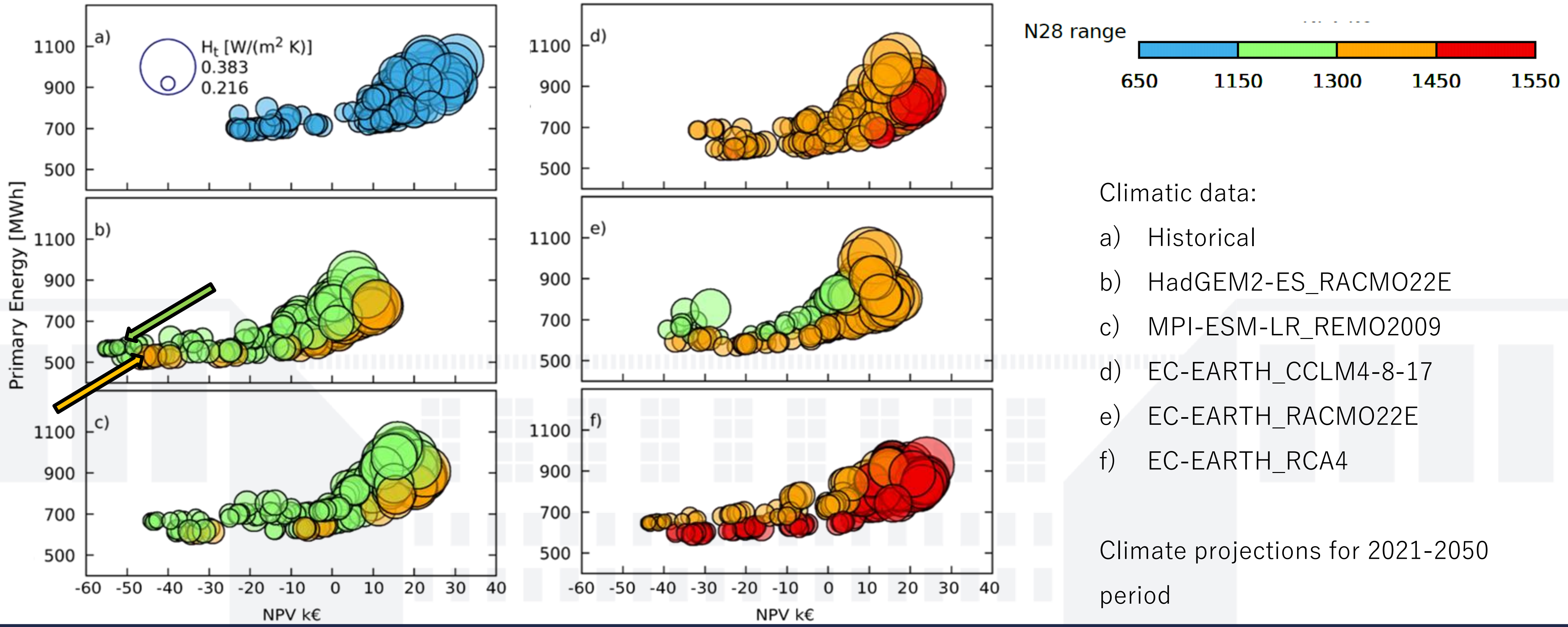


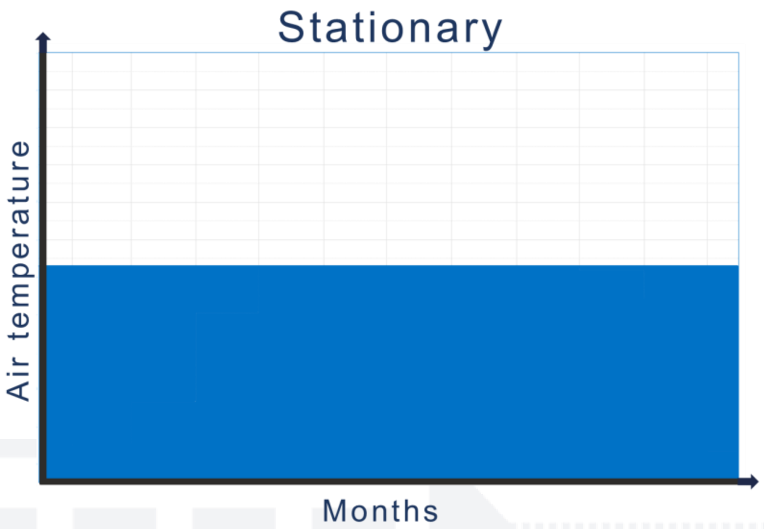
Climatic data:

a) Historical
b) HadGEM2-ES_RACMO22E
c) MPI-ESM-LR_REMO2009
d) EC-EARTH_CCLM4-8-17
e) EC-EARTH_RACMO22E
f) EC-EARTH_RCA4

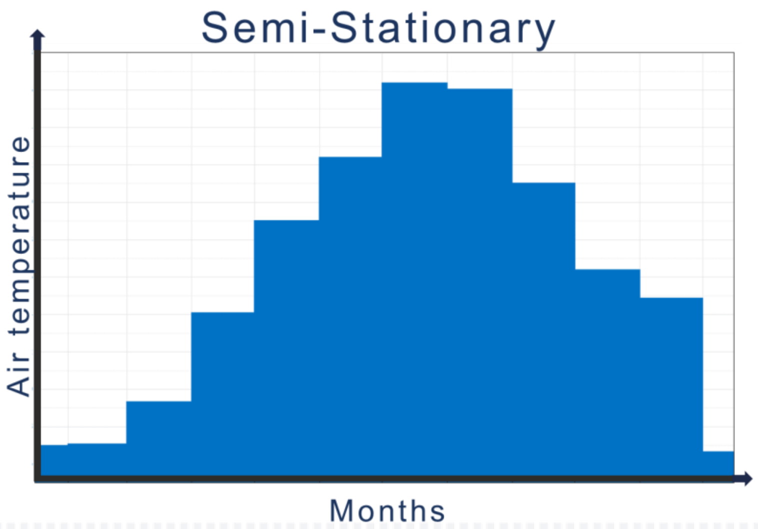
Climate projections for 2021-2050 period

Simulation models impact on the evaluation of energy consumption

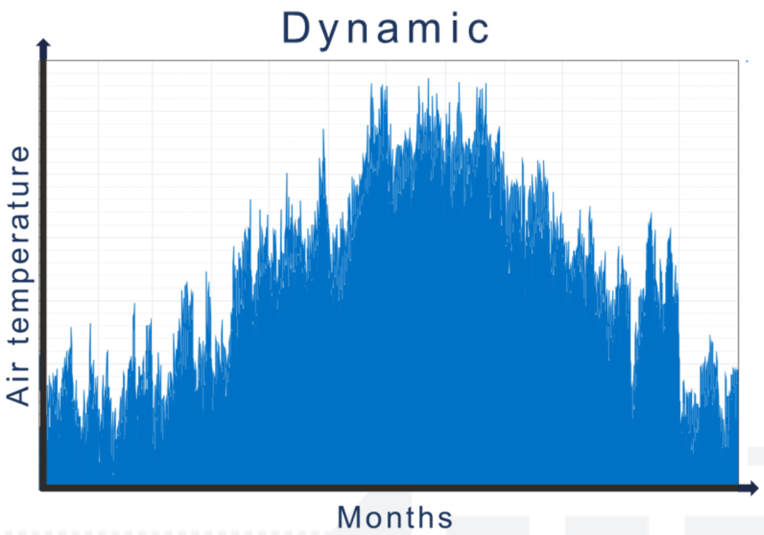
Different types of simulation models



Rarely used



Underlying commercial softwares (EPC, regulations checks)



Mostly used in research

− Results precision +

Required computing power

Simulation models impact on the evaluation of energy consumption

Different types of simulation models

Stationary model uses yearly average values:

- The main advantage is the reduced computation time

Semi-stationary model uses monthly average values and allows to consider:

- Building seasonal thermal inertia
- Seasonal dwellers behavior
- Seasonal influence of external climate

Dynamic model uses hourly average values and allows to consider:

- Building intra-daily thermal inertia (especially important in summer season)
- Detailed dwellers behavior
- Detailed influence of the external climate in particular intra-daily swings of solar radiation, air temperature and relative humidity

Energy buildings design, efficiency solutions and their implementation

First steps of building energy design

What is the first thing to do when a client asks to design a energy refurbishment of an existing building?

→ Gather information, and then more information, and then even more information!

What kind of information is useful for energy design?

- Building location and correlated features
  - External climate information
  - Presence of possible external shading elements (hills, buildings, trees, etc.)
  - Technical rules to apply (i.e. General Municipal Master Plan)

- Building geometry
  - Floors plans
  - Sections
  - Prospects

Energy buildings design, efficiency solutions and their implementation

First steps of building energy design

- Building envelope
  - Characteristic of every material present in the building envelope
  - Stratigraphy of every building opaque element involved in the analysis
  - Technical features of every windowed element of the building

- Building technical systems
  - Checking the presence of HVAC systems (heating, ventilation, air conditioning)
  - Checking the presence of domestic hot water production, lighting and lifting systems
  - For heating, cooling and DHW production systems assessing the features of:
    - Emission subsystem
    - Distribution subsystem
    - Regulation subsystem
    - Generation subsystem
  - Assessing the type of ventilation (natural, mechanical) and its characteristics

Energy buildings design, efficiency solutions and their implementation

First steps of building energy design

- Building usage
  - Characteristic of the activities inside the building
  - Behavior pattern of dwellers

- Client needs and targets

<u>What are the best ways to assess all these information?</u>

- On-site inspections
- Research of historical data (architectural, technical, etc.)
- Energy audit
  - Detect energy consumption historical data (bills, report, etc.)
  - Usually has a higher level of detail than the modelling carried on to check technical requirements
  - Identifies the best solution for energy refurbishment

Energy buildings design, efficiency solutions and their implementation

Modelling the state of the art and the refurbishment interventions

The state of the art of the analyzed building is represented through a numerical model created with commercial softwares (i.e. EC700, Thermolog, etc.) including:

- Envelope
- Technical systems
- Usage patterns and dwellers behavior

What is important to do first with this numerical model?

→ Compare it to the results of the energy audit to calibrate it for modelling refurbishment interventions

→ The results will probably not be totally coincident because of the different approach used for the energy audit

An Energy Performance Certificate is drafted, determining the energy class of the state of the art building

The numerical model of the state of the art is then duplicated to model the refurbishment interventions (chosen on the basis of energy audit and to satisfy client needs) and to compare the results of current and designed configurations

Energy buildings design, efficiency solutions and their implementation

Technical and economical checks of the interventions

The modelled refurbishment interventions fall within one of the type of interventions defined in the I.D. 26 June 2015:

- New buildings
- Major first level renovations
- Major second level renovations
- Energy requalifications

→ All the related technical requirements must be checked and satisfied

The economic return of the investments shall be always determined (usually by computing the Net Present Value of the investment)

An Energy Performance Certificate is drafted, determining the energy class of the refurbished building

More than one refurbishment solution shall be designed, complete with all the aforementioned informations, to give the client the chance to choose between different solutions and outcomes

When the client chooses the intervention to be carried on, the technical details are designed and checked