Institutional setting

- 2012 was an important year in the history of the construction industry in Serbia. In October 2012 the *Ordinance on energy efficiency of buildings* and *Ordinance on the conditions, content and method of publishing certificates of buildings energy performance* came into effect.
- *Ordinance on energy efficiency of buildings* explains in detail the method for the calculation of the buildings heating energy performances and energy requirements for new and existing buildings.
- On the basis of *Ordinance on the conditions, content and method of publishing certificates of buildings energy performance*, all new buildings and existing buildings that are reconstructed, adapted, retrofitted or energy retrofitted must have the energy certificates.
- The ordinances imposed a legal obligation for the construction of new energy efficient buildings, so from todays point of view, all multi-family residential buildings constructed before 2012 are practically energy inefficient.

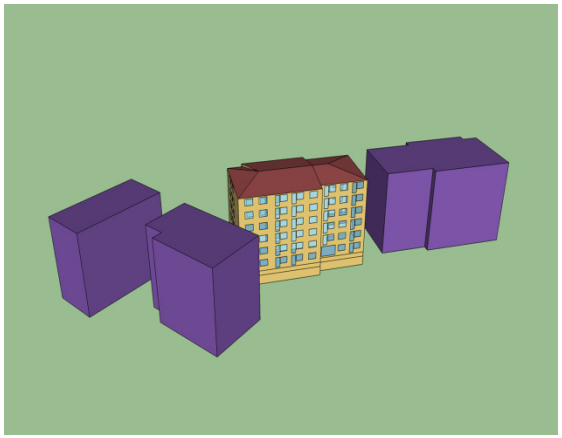
Starting point

- The national level database of published building energy certificates would provide information on the energy performance of building sector. However, the energy performances data of the existing buildings that will not be reconstructed, adapted, retrofitted and energy retrofitted, would not be collected. This especially applies to the multifamily (more than four apartments) residential building sector, which consummates the great amount of energy for the heating purpose.
- Multifamily residential buildings, with their complex ownership structure, represent buildings that will be very difficult to reconstruct, adapt, retrofit or energy retrofit.

Approach

- The engineering bottom-up methodology was developed for modeling the heating energy consumption of a multi-family residential building sector built before 2012 in the city of Kragujevac in Serbia.
- The methodology steps are:

1. Development of the criteria based on which a multi-family residential building sector of the city was described and building types were defined,
2. Modeling of the sample real buildings in Google SketchUp and EnergyPlus software,
3. Heating energy consumption simulation of building models performed in EnergyPlus software,
4. Heating energy consumption optimization simulation by improving the thermal envelope of buildings.



Outputs

- Estimated heating energy consumption of a multifamily residential building sector in the city of Kragujevac in Serbia.
- 10 cm thick thermal insulation addition to external walls.
- New windows installation with U=1.4 W/Km^2

Energy class		kWh/m^{2}a
C		≤70
D		≤105
E		≤140
F		≤175
G		>175

Lessons

- Heating energy optimization was investigated on three hierarchical levels in the city of Kragujevac.
- Thermal envelope improvements: installation of thermal insulation (10 cm thick polystyrene) on the external walls and installation of new windows (U=2.2 W/Km^2 and U=1.4 W/Km^2).
- The biggest reduction of heating energy consumption of multi-family residential buildings after the individual improvement is 22.8%, while maximum reduction after the combination of improvements is 31.56%. The reduction in heating energy consumption of 37.52% would be achieved in the free-standing buildings, constructed between 1961 and 1970, after the installation of thermal insulation on the external walls. The reduction in heating energy consumption of 37.61% would be achieved in the high-rise buildings, constructed in the period 1971-1980, after the installation of new windows.

Follow up

- The methodology limitations:

1. Heating energy consumption of the building models was calibrated on the basis of measured energy consumption from two heating seasons,
2. The accuracy of calculation results depends on the residential heated area of the buildings, which are partly determined by an approximate method.

- Further research can include heating energy consumption optimization by:

1. Introduction of the renewable energy systems,
2. Reduction of the internal air temperature,
3. Changes in the occupants behavior...