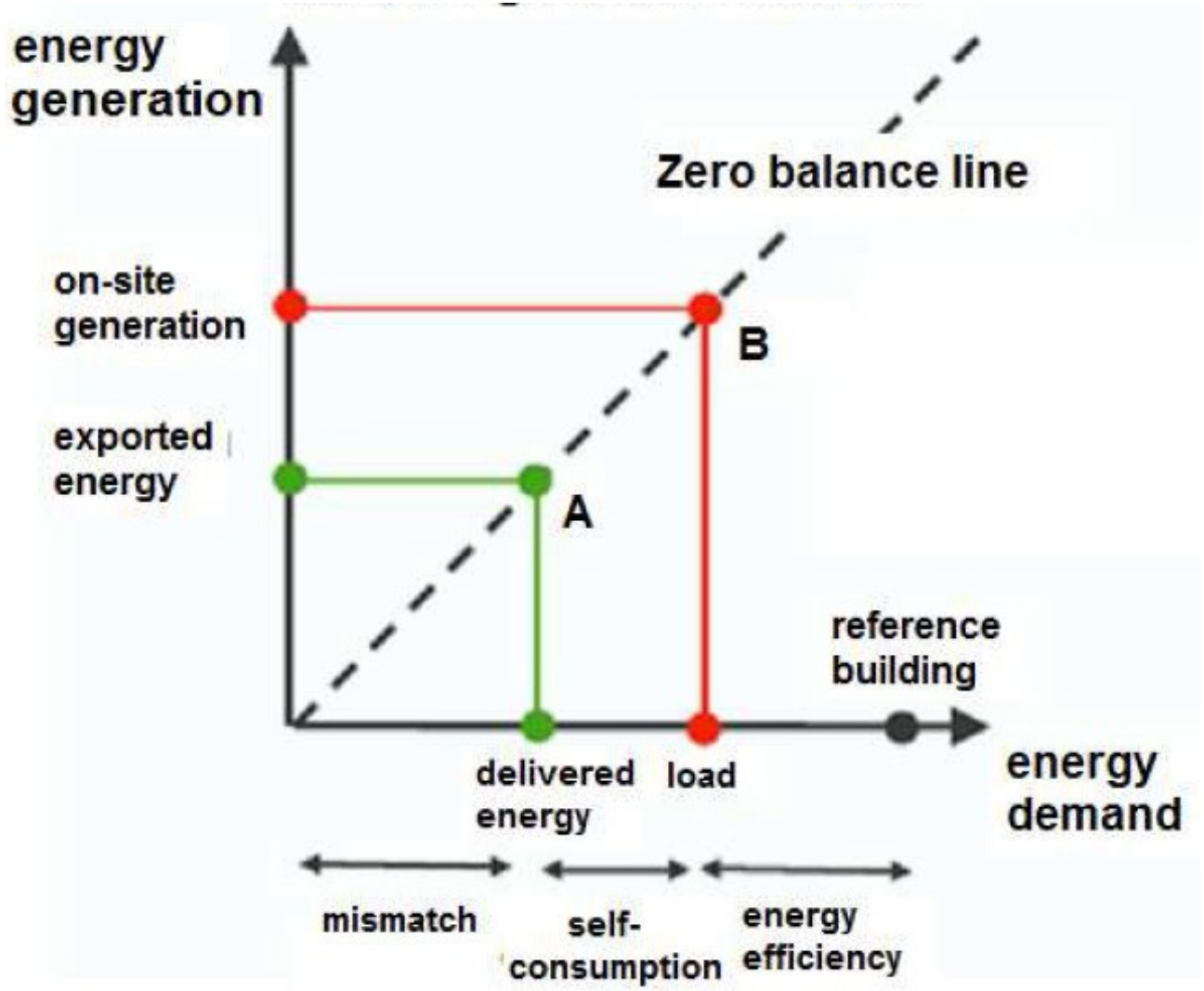
Impact of HVAC system selection on possibility to reach nearly zero energy residential building in Serbia

Marko G. Ignjatović, Bratislav D. Blagojević,
Milena B. Blagojević, Dragana D. Temeljkovski

Improving building energy performance

- Building sector – most energy demanding across the globe
- EPBD recast and EED – turning point in design and construction of new buildings
- Building stock turnover rate is very low – existing buildings refurbishment is of the great interest for achieving goals
- EPBD 2010/31/EU and revised EPBD 2018/844/EU:
  - nZEB;
  - Primary energy
  - Cost-optimal measures.
- Energy renovation – economically feasible for end user during building lifecycle
- Long term renovation strategy – mandatory for EU member states – 2050 highly efficient and decarbonized building sector

Improving building energy performance



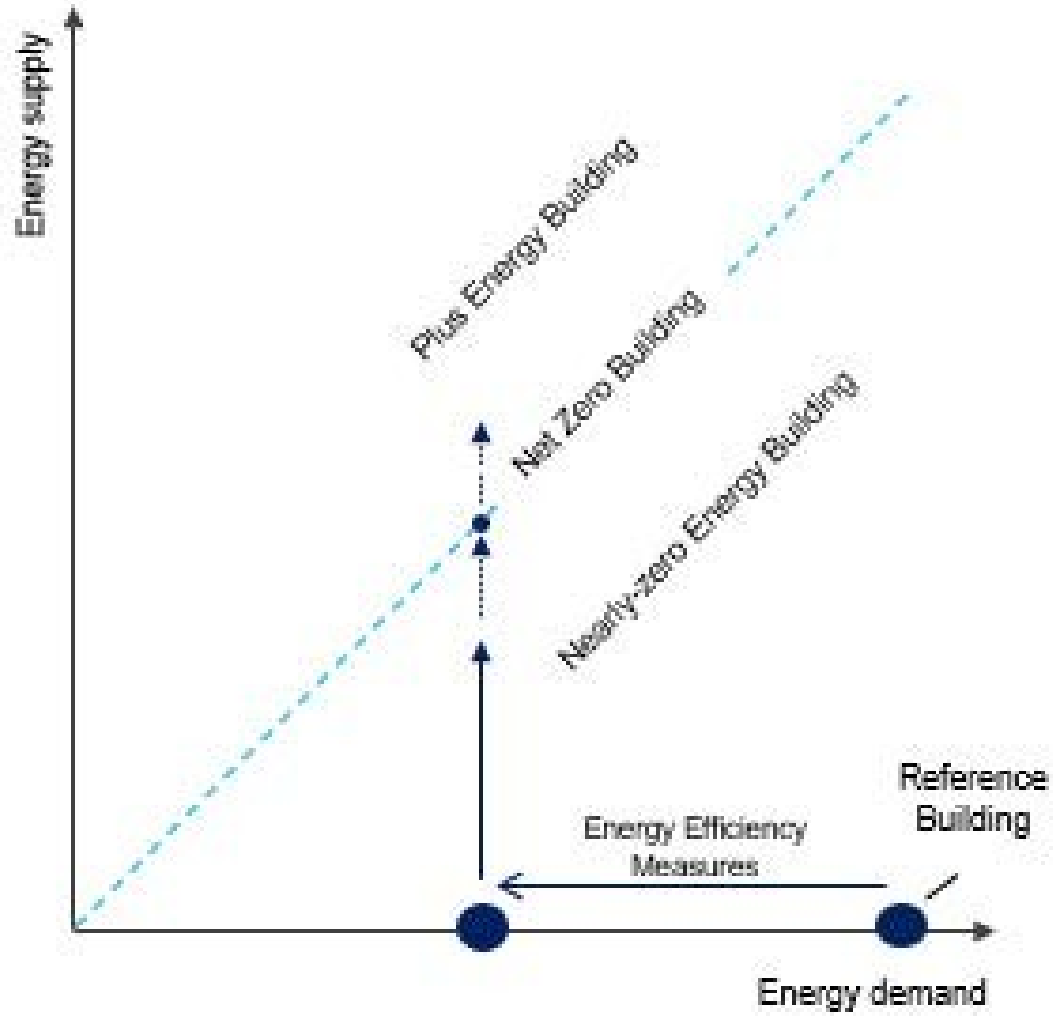
Situation in Serbia

- Most of the EU legislation in building energy performance put in practice in some form and shape – Energy Certificate for building permit (seasonal approach for EP, without cooling energy needs) – new buildings and buildings under major renovation
- Residential buildings – the most numerous type (both in number and in building area) – problems with multi-family residential (apartment) buildings in cities due to ownership
- Analyzing the potential for improving existing building EP toward nZEB – technical part

Situation in Serbia

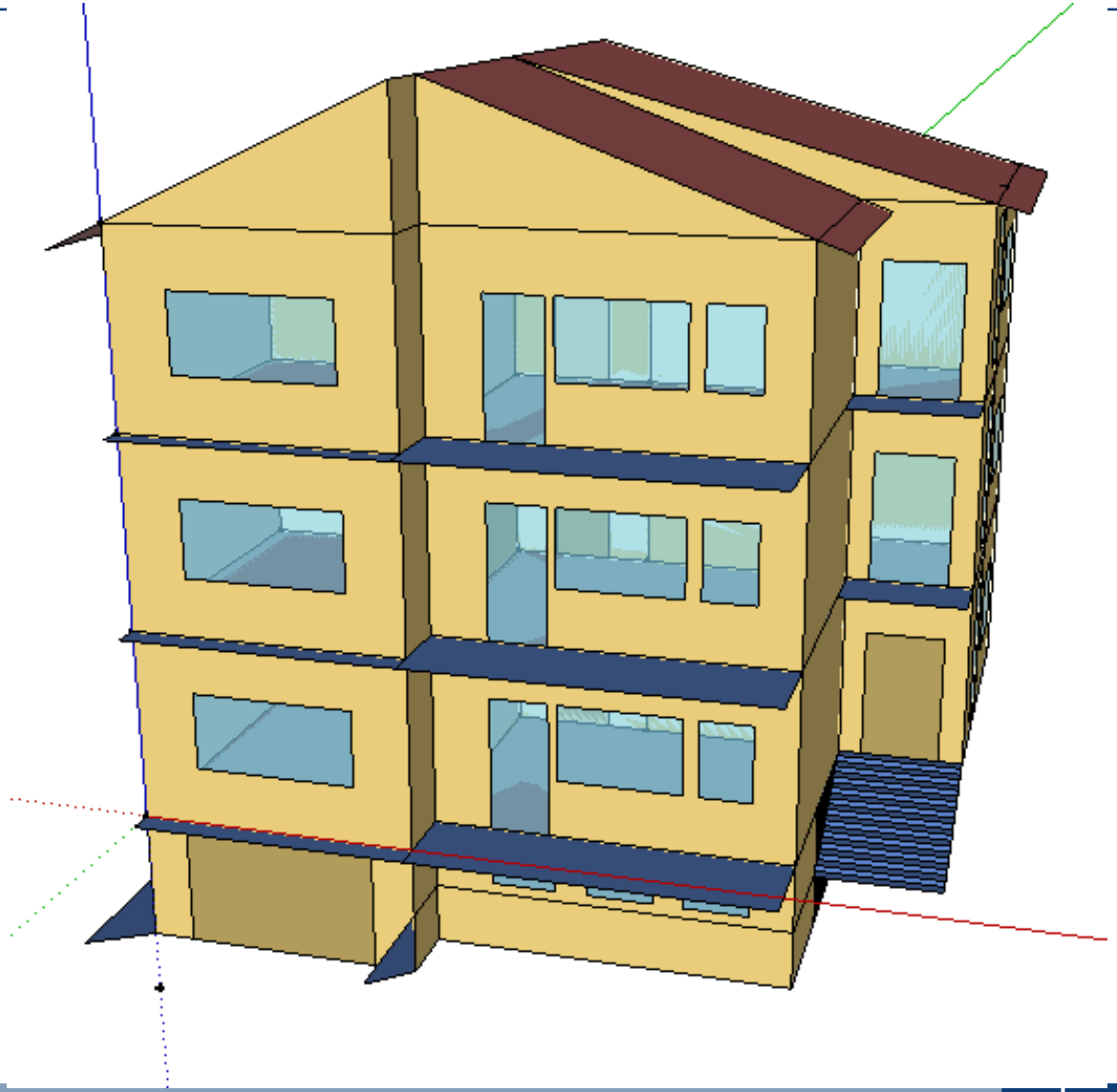
- Lacking typology for most building types and uses – some individual efforts have been made especially for public buildings – creating baseline (building energy models) with necessary input data very difficult task – some generalization and simplification must be made
  1. According to period of construction
  2. Number of building stories;
  3. According to location and disposition – very heterogenic throughout the country;
  4. Primary energy used;
  5. HVAC and other systems
  6. Building usage and occupancy profiles, etc.

Where are we at the moment?



Case study building and systems

- Total floor area of ≈ 350m^2
- Built in the early 1980s
- Simplification: heating setpoint 22^{o}C and cooling 26^{o}C
- Heating season starts on October 15th and ends on April 15th
- The roof of the building: free for generating electricity from PV panels,
- assumption PV panels will have small-to-none effect on the overall building energy balance,
- roof is tilted 15^o and 25^o toward E and W respectively



Case study building and systems

Construction	Material	Thickness [m]	U-value [W/m2K]
External wall	Mortar	0.015	0.76
	Polystyrene	0.03	
	Brick	0.25	
	Mortar	0.015	
Floor toward unconditioned basement/floor on ground	Floor tiles	0.015	≈0.74
	Insulation	0.02	
	Concrete	0.1	
	Concrete	0.25	
	Mortar	0.015	
Ceiling towards unconditioned roof area	Stone wool	0.05	0.77
	Concrete plate	0.25	
	Mortar	0.015	
Windows	Double glazed, air filled	4-12-4mm	3.0, SHGC=0.71

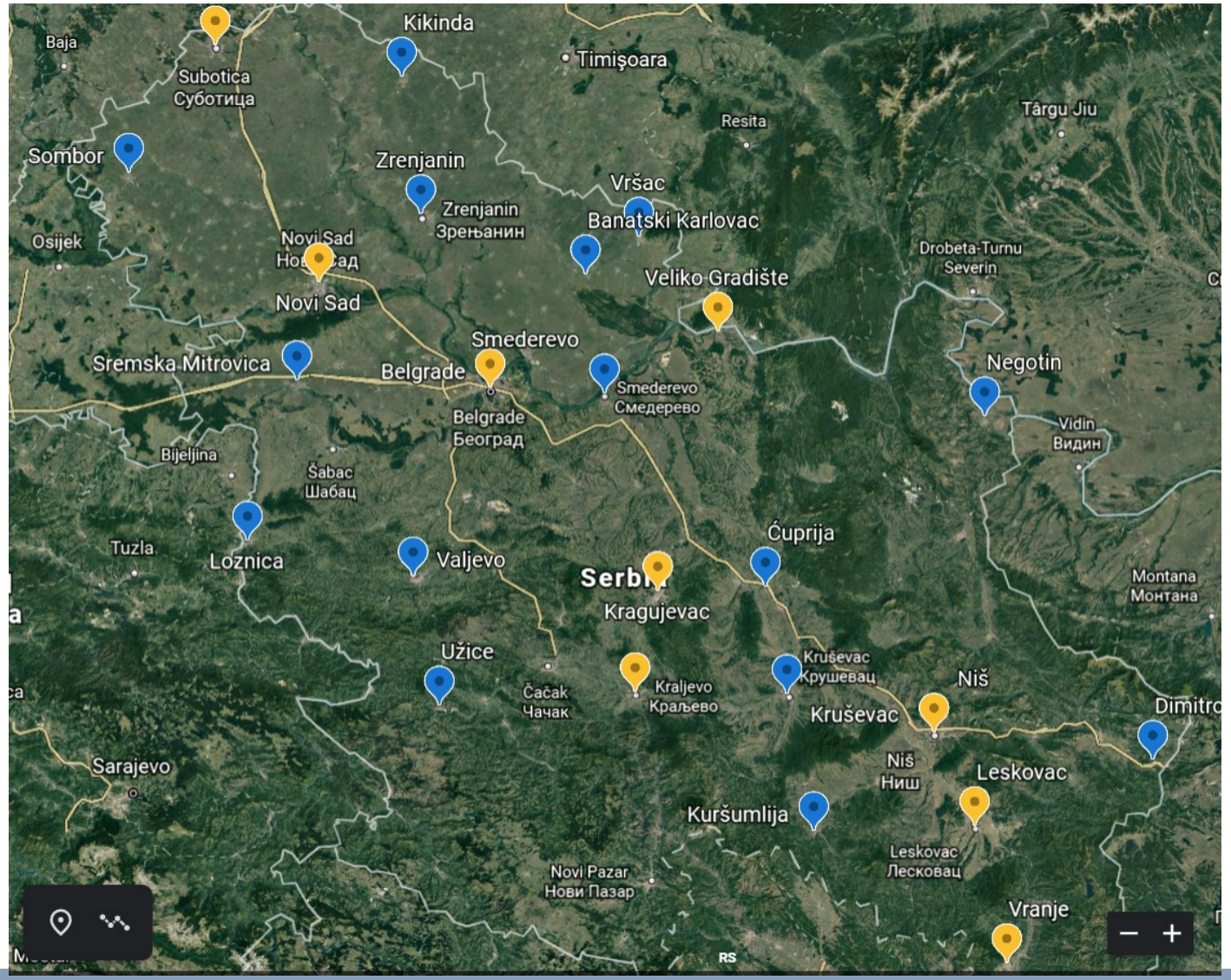
Analyzed cases of refurbishment

- Building envelope components do not satisfy minimum energy performance requirements, two refurbishment options:
  - Refurbishment for minimum energy performance according to national ordinance on EE - “Legislative” (7cm insulation on outside walls, 3cm insulation in floor toward unheated basement and 5cm insulation toward unheated roof and replacing windows with new ones (U-value of 1.5W/m2K, SHGC=0.61))
  - Refurbishment for high energy performance - “Passive”, (17cm insulation on outside walls, 6cm insulation in floor toward unconditioned basement and 5cm insulation toward unconditioned roof and replacing windows with new ones (U-value of 0.7W/m²K, SHGC=0.48))

Building HVAC systems

- Ideally sized and controlled HVAC systems (or combinations) have been modelled for thermal zones:
  - Radiator heating system for space heating in combination with split-type DX air-conditioners,
  - Fan-coil system for both space heating and space cooling,
- As the primary energy source, the following energy supply combinations have been modelled:
  - For providing energy for space heating either gas condensing boiler (CGB) or district heating (DH),
  - For providing energy for space cooling air-cooled water chiller has been modeled.
- All HVAC components were taken from EnergyPlus libraries, and represent generic components, without any manufacturer data preference

Locations in Serbia and PV potential



Locations in Serbia and PV potential

Location	PV produced	Location	PV produced
Subotica	15520	Negotin	16577
Kikinda	15879	Valjevo	16381
Sombor	15874	Kragujevac	16672
Zrenjanin	16238	Užice	13846
Novi Sad	14963	Ćuprija	16629
Vršac	15680	Kraljevo	16146
Sremska Mitrovica	15908	Kruševac	16420
Banatski Karlovac	16074	Niš	16119
Beograd	16226	Kuršumlija	15933
Veliko Gradište	16280	Leskovac	17012
Smederevo	16132	Dimitrovgrad	16908
Loznica	15376	Vranje	17564

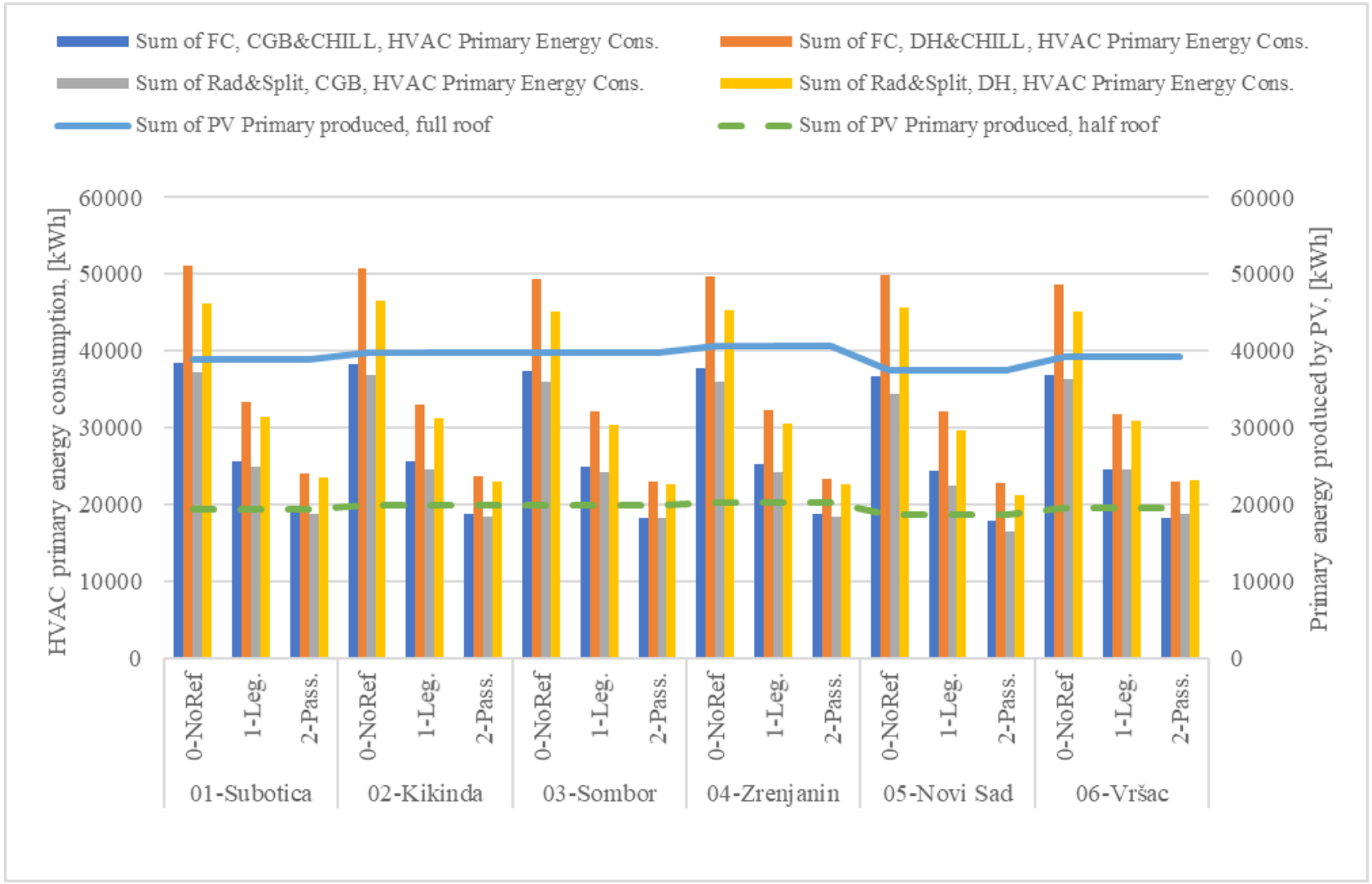
Results

Location	Refurbishment Level	Fan Coil Boiler& Chiller Heating Energy consumption [kWh]	Fan Coil Boiler& Chiller Electricity consumption for cooling [kWh]	Fan Coil District Heating& Chiller Heating Energy consumption [kWh]	Fan Coil District Heating& Chiller, Electricity consumption for cooling [kWh]
01-Subotica	0-NoRef	26816	3612	23335	3611
	1-Leg.	14711	3750	13293	3746
	2-Pass.	9398	3430	8630	3424
04-Zrenjanin	0-NoRef	24482	4310	21641	4303
	1-Leg.	13152	4308	11994	4298
	2-Pass.	8204	3866	7590	3856
05-Novi Sad	0-NoRef	26527	3017	23553	3016
	1-Leg.	14458	3423	13131	3416
	2-Pass.	9026	3198	8274	3189
07-Sremska Mitrovica	0-NoRef	25565	3801	22367	3798
	1-Leg.	13793	3957	12456	3950
	2-Pass.	8605	3549	7898	3542
09-Beograd	0-NoRef	21577	4288	19070	4281
	1-Leg.	11099	4352	10183	4342
	2-Pass.	6642	3933	6184	3925
12-Loznica	0-NoRef	23107	3919	20224	3914
	1-Leg.	12660	4036	11409	4028
	2-Pass.	7959	3681	7244	3673

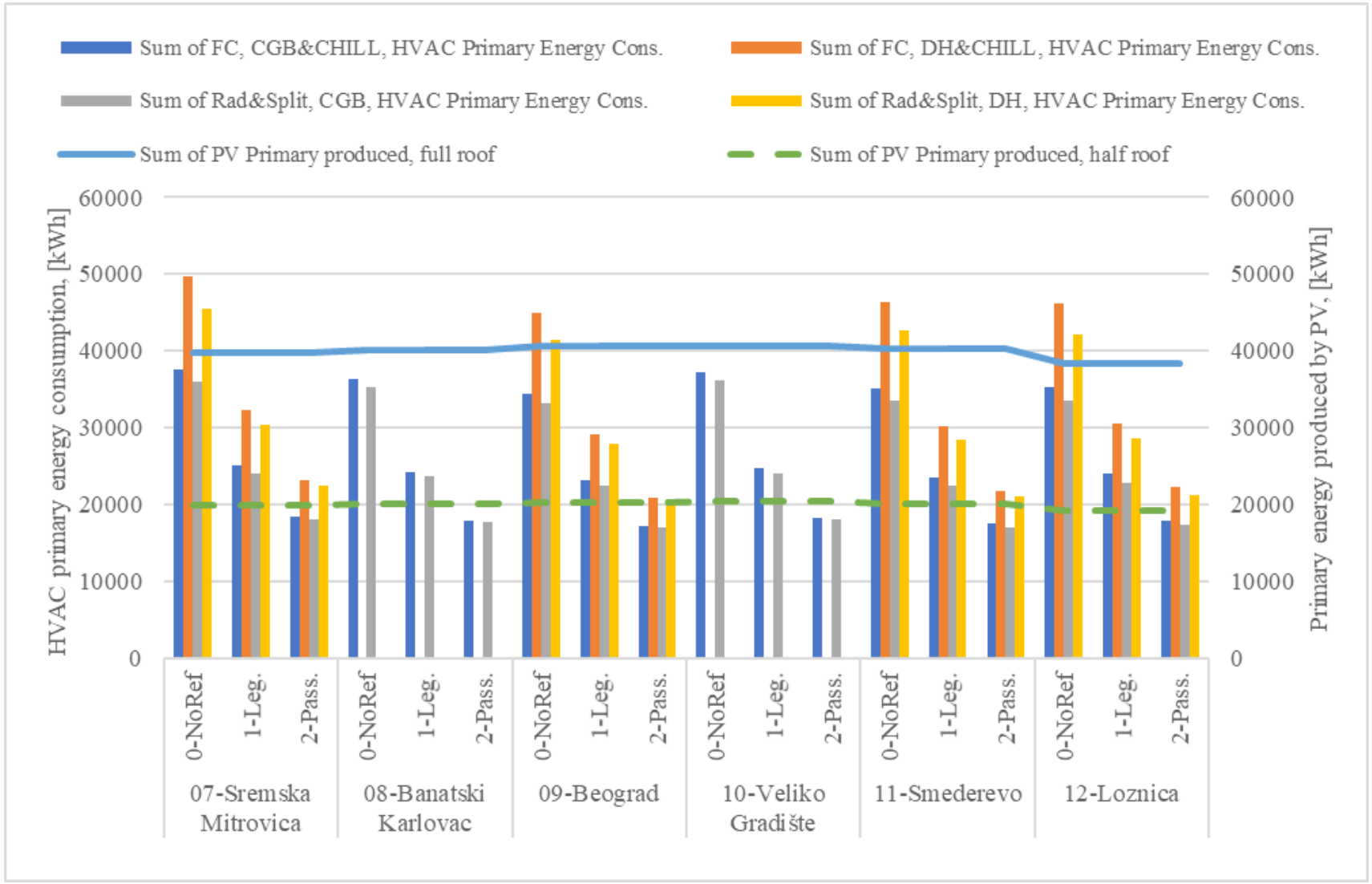
Results

Location	Refurbishment Level	Radiators&Split, Boiler Heating Energy Consumption [kWh]	Radiators&Split, Boiler Electricity consumption for cooling [kWh]	Radiators&Split, District Heating, Heating Energy Consumption [kWh]	Radiators&Split, District Heating, Electricity consumption for cooling [kWh]
01-Subotica	0-NoRef	27168	2928	21594	2928
	1-Leg.	15046	3367	12785	3366
	2-Pass.	9622	3304	8488	3302
04-Zrenjanin	0-NoRef	24979	3403	20468	3402
	1-Leg.	13473	3774	11773	3773
	2-Pass.	8421	3632	7569	3631
05-Novi Sad	0-NoRef	27145	1816	22799	1816
	1-Leg.	14813	2434	13079	2428
	2-Pass.	9267	2530	8318	2528
07-Sremska Mitrovica	0-NoRef	26006	2971	21133	2973
	1-Leg.	14131	3426	12151	3423
	2-Pass.	8859	3357	7838	3354
09-Beograd	0-NoRef	21890	3628	17971	3629
	1-Leg.	11365	3974	9966	3971
	2-Pass.	6807	3811	6169	3808
12-Loznica	0-NoRef	23519	3084	19163	3084
	1-Leg.	12967	3418	11120	3414
	2-Pass.	8177	3328	7171	3327

Results


Sum of FC, CGB&CHILL, HVAC Primary Energy Cons.
Sum of FC, DH&CHILL, HVAC Primary Energy Cons.
Sum of Rad&Split, CGB, HVAC Primary Energy Cons.
Sum of Rad&Split, DH, HVAC Primary Energy Cons.
Sum of PV Primary produced, full roof
Sum of PV Primary produced, half roof
HVAC primary energy consumption, [kWh]
Primary energy produced by PV, [kWh]
60000
50000
40000
30000
20000
10000
0
0-NoRef
1-Leg.
2-Pass.
01-Subotica
02-Kikinda
03-Sombor
04-Zrenjanin
05-Novi Sad
06-Vršac

Results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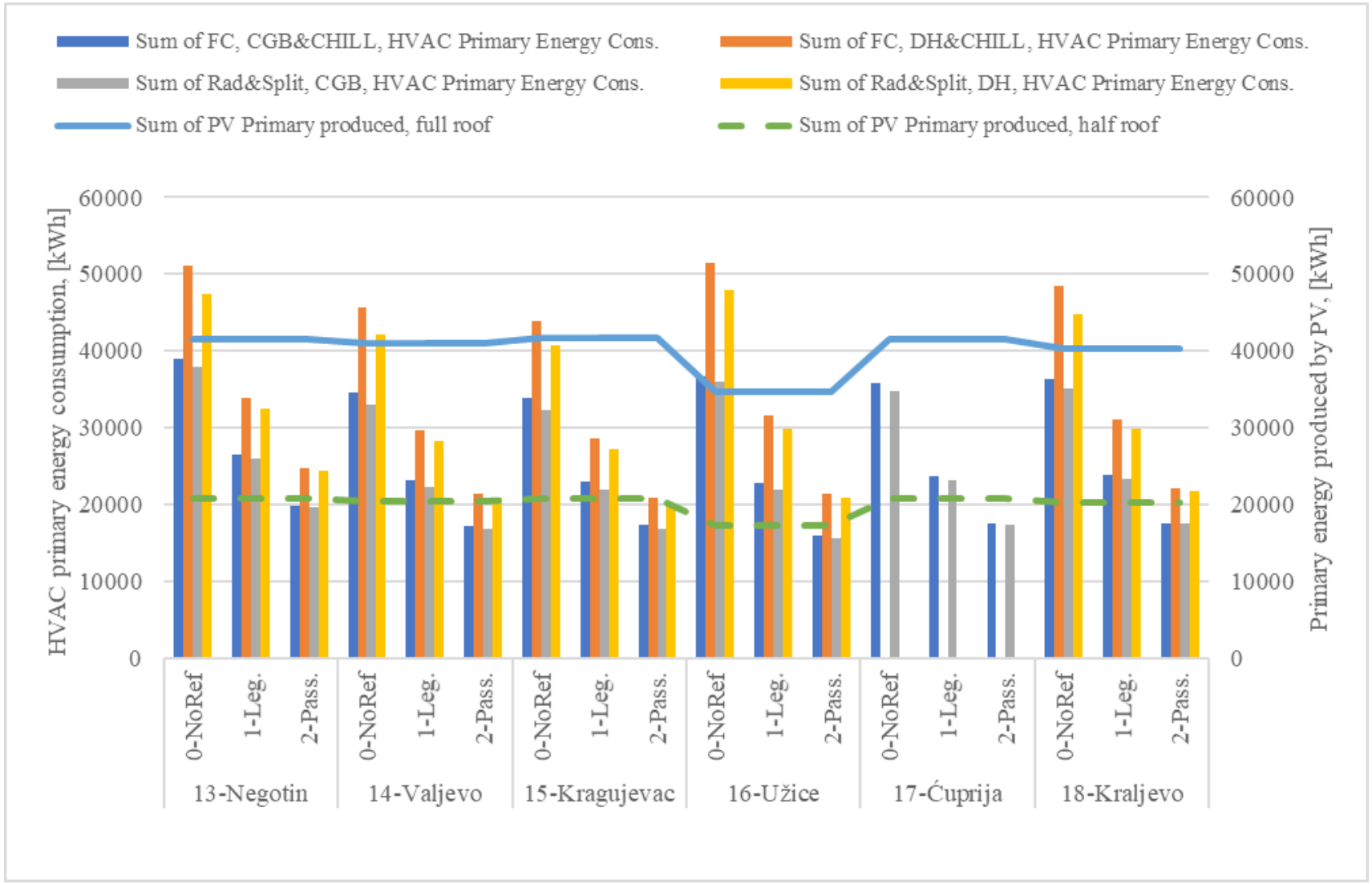
Sum of PV Primary produced, full roof
Sum of PV Primary produced, half roof
HVAC primary energy consumption, [kWh]
Primary energy produced by PV, [kWh]
60000
50000
40000
30000
20000
10000
0
0-NoRef
1-Leg.
2-Pass.
07-Sremska Mitrovica
08-Banatski Karlovac
09-Beograd
10-Veliko Gradište
11-Smederevo
12-Loznica

Results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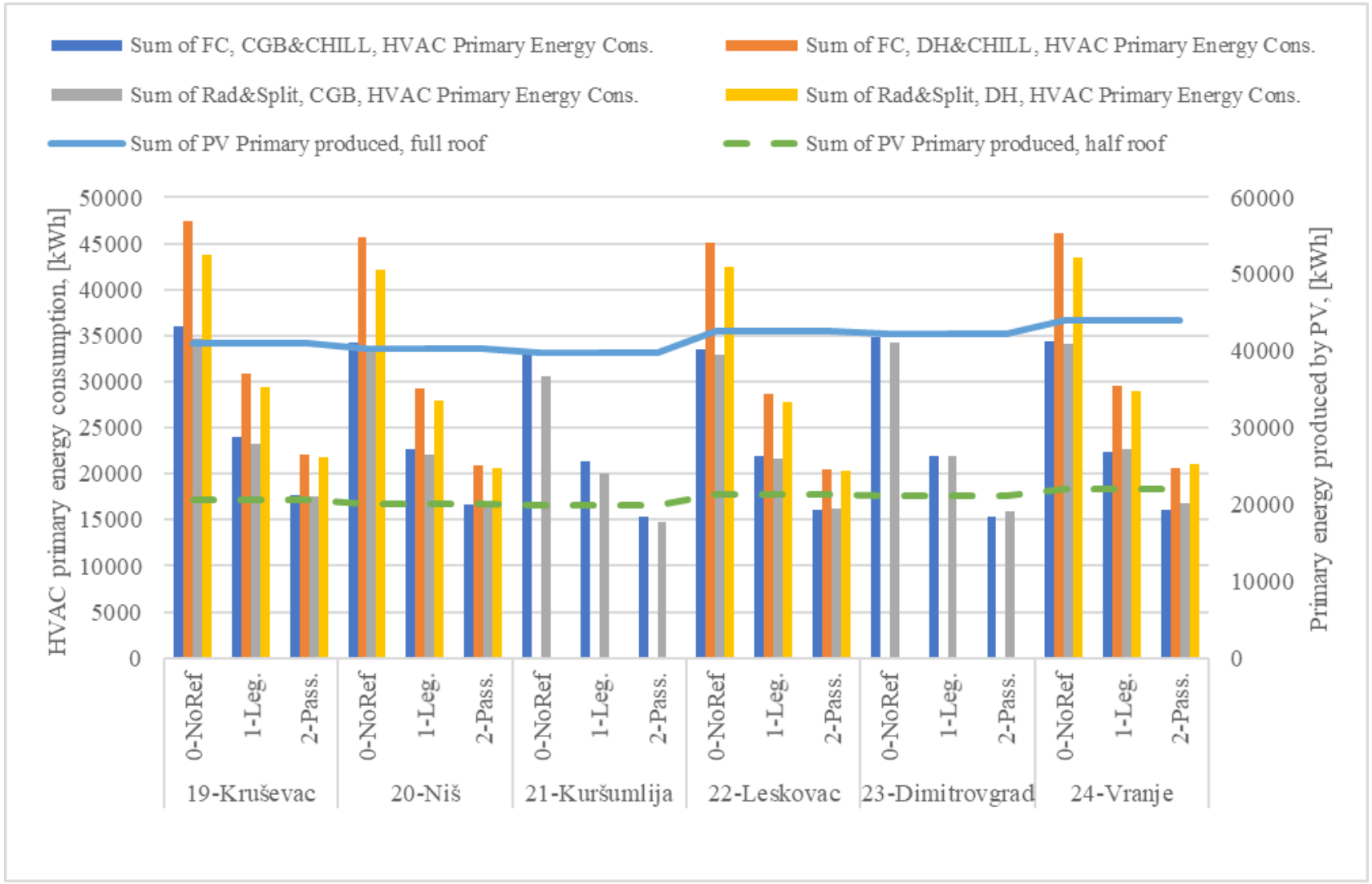
Sum of Rad&Split, DH, HVAC Primary Energy Cons.
Sum of PV Primary produced, full roof
Sum of PV Primary produced, half roof
HVAC primary energy consumption, [kWh]
Primary energy produced by PV, [kWh]
60000
50000
40000
30000
20000
10000
0
0-NoRef
1-Leg.
2-Pass.
13-Negotin
14-Valjevo
15-Kragujevac
16-Užice
17-Ćuprija
18-Kraljevo

Results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Sum of FC, DH&CHILL, HVAC Primary Energy Cons.
Sum of Rad&Split, CGB, HVAC Primary Energy Cons.
Sum of Rad&Split, DH, HVAC Primary Energy Cons.
Sum of PV Primary produced, full roof
Sum of PV Primary produced, half roof
HVAC primary energy consumption, [kWh]
Primary energy produced by PV, [kWh]
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
60000
50000
40000
30000
20000
10000
0
0-NoRef
1-Leg.
2-Pass.
19-Kruševac
20-Niš
21-Kuršumlija
22-Leskovac
23-Dimitrovgrad
24-Vranje

Results

- when heating energy is provided by district heating, there is a slight reduction compared to cases when heating is provided by condensing gas boiler
- In most locations in Serbia produced electricity (converted to primary energy) from roof can balance the primary energy used for heating and cooling with proper envelope refurbishment, which is a good starting point for further research

Conclusion

- In Serbia, there is an energy potential (in Solar energy throughout the country, in some parts other RES) to refurbish residential buildings of this type towards nZEB, by implementing PV panels on the roof to balance not only the energy consumption for space heating and cooling, but for other end-uses
- Only several combinations of HVAC secondary and primary systems have been analyzed, and in all cases, it is found than for most locations very small envelope improvements can give the expected results.

THANK YOU FOR THE ATTENTION!

marko.ignjatovic@masfak.ni.ac.rs