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Modelling the impact of installation of heat cost allocators in DH systems using decision tree model

Danica Maljković
Dražen Balić
Energy Institute Hrvoje Požar, Croatia

AALBORG UNIVERSITY
DENMARK

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4DH
4th Generation District Heating
Technologies and Systems

Introduction

- EU regulation on energy efficiency, Article 9, introducing mandatory individual metering
- Due to bad communication to the consumers a false perception of HCA was created as devices that save energy by themselves
- Big public disagreement campaign in the press in 2015 in Croatia
- The question – does implementation of HCA result in the energy savings?

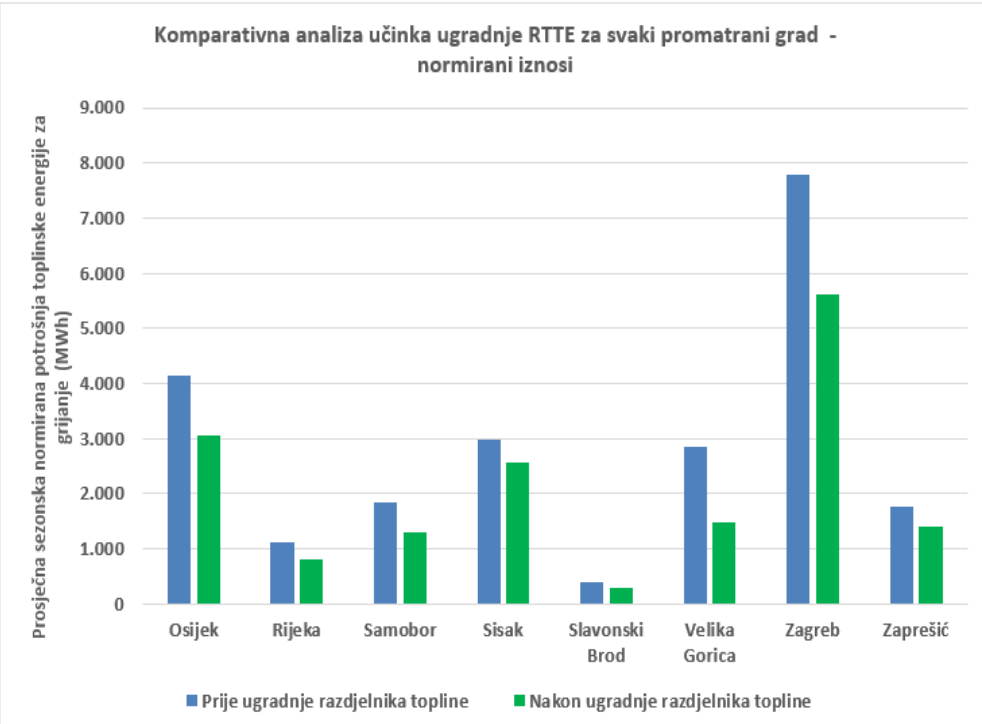
Source: graphic EnBW, VGB, www.vgb.org

Heat Consumption (in DH)

- Depends on a number of parameters of which some measurable and predictable, while other are hard to predict
- Measurable/predictable:
  - building envelope characteristics
  - heating degree days (climatology)
  - number of occupants
  - schedule of space usage
  - energy source
  - building heat installation losses (including heating substation)
  - position of the apartment in the building
  - formula for calculating consumption in case of HCA
  - *existence of individual metering*
- Hard to predict:
  - heat gains/losses form adjacent apartments
  - heat comfort level in the apartment
  - mode od space usage (opening windows)
  - income level of the owner, readiness to pay

Source: graphic EnBW, VGB, www.vgb.org

Evaluation of savings based on HDD – 27,7%



Town	Heat consumption reduction, HDD
Osijek	26,3%
Rijeka	28,3%
Samobor	28,0%
Sisak	14,0%
Slavonski Brod	22,2%
Velika Gorica	48,0%
Zagreb	27,8%
Zaprešić	21,3%

Taking only climatology into account. Savings on the building level.
Are the savings result only of HCA installment?

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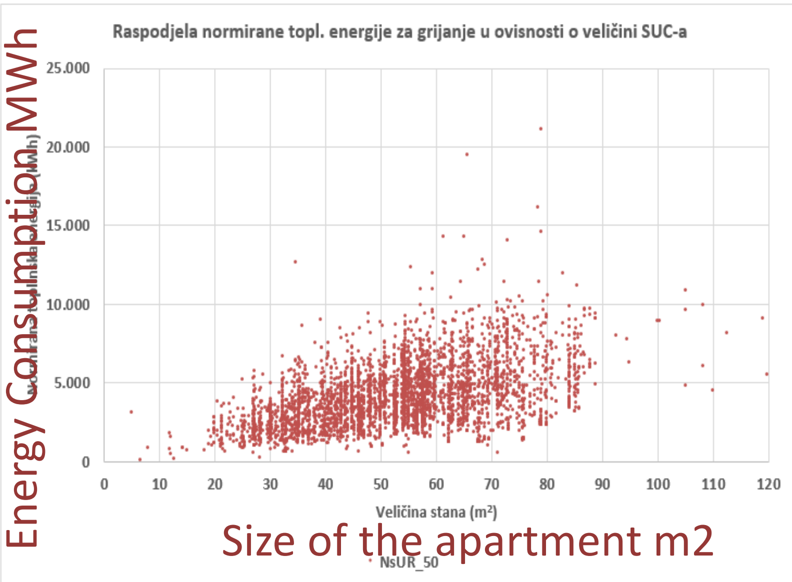
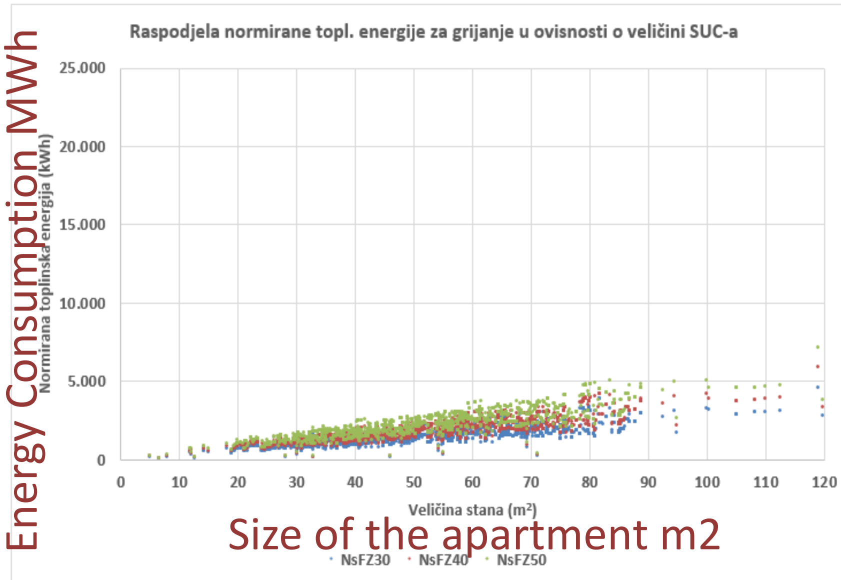
Source: graphic EnBW, VGB, www.vgb.org

What happens on the apartment level?

- Adjescent apartmets, formula, occupancy and way of usage?





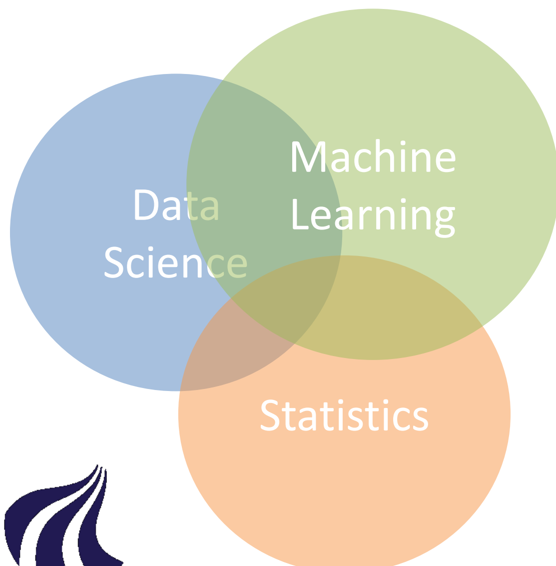
Change in scattering of „consumption” due to the change in the formula. Influences cost.

Installment of HCA reduces cost for most, but not all, of the apartments.

Investment in HCA is made by the consumer. How and when is HCA EE measure?

Predicting what is hard to predict

- building energy consumption modelling and the usual methods used are traditional multiple regression models, simulation methods and methods of artificial neural networks
- in the last years machine learning has gain larger application in various fields – „chewing of data”
- gives good results in cases where large amounts of data are to be processed with an aim to recognize a pattern and correlation of each of the relevant parameter as well as in the cases where the problem is too complex for a human intelligence to solve
- decision tree method, has proven an accuracy of over 92% in prediction general building consumption



<u>Interdisciplinary</u>

1. Programming
2. Expertise in the field
3. Mathematics&Statistics

<u>Three steps</u>

1. Data work
2. Choosing of an algorithm
3. Developing a model

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Source: graphic EnBW, VGB, www.vgb.org

6 steps in production

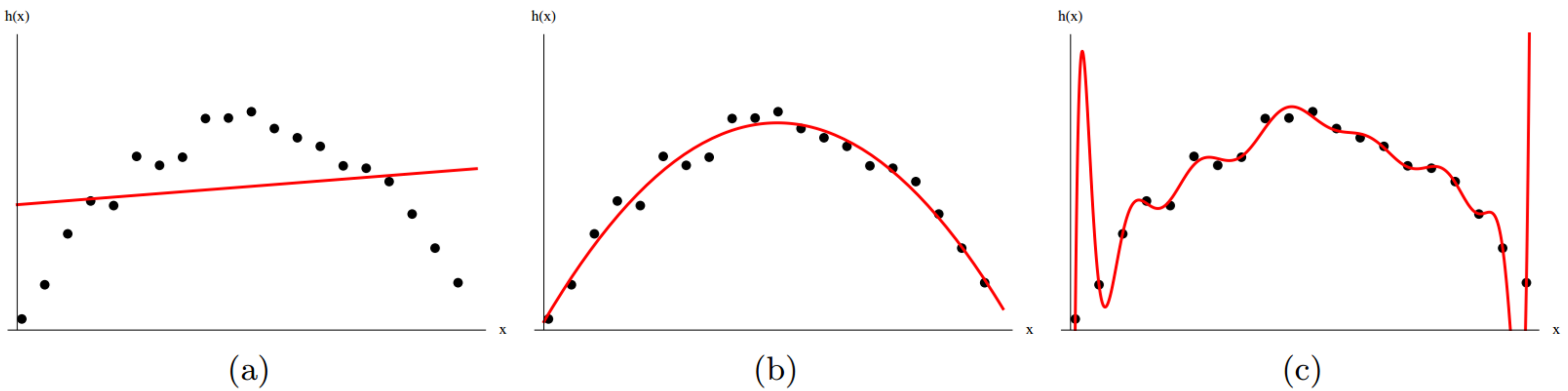
1. Data preparation
2. Data description
3. Learning
4. Evaluation
5. Diagnosis
6. Deployment

Source: graphic EnBW, VGB, www.vgb.org

Learing algorithm

1. Model
2. Error
3. Optimization

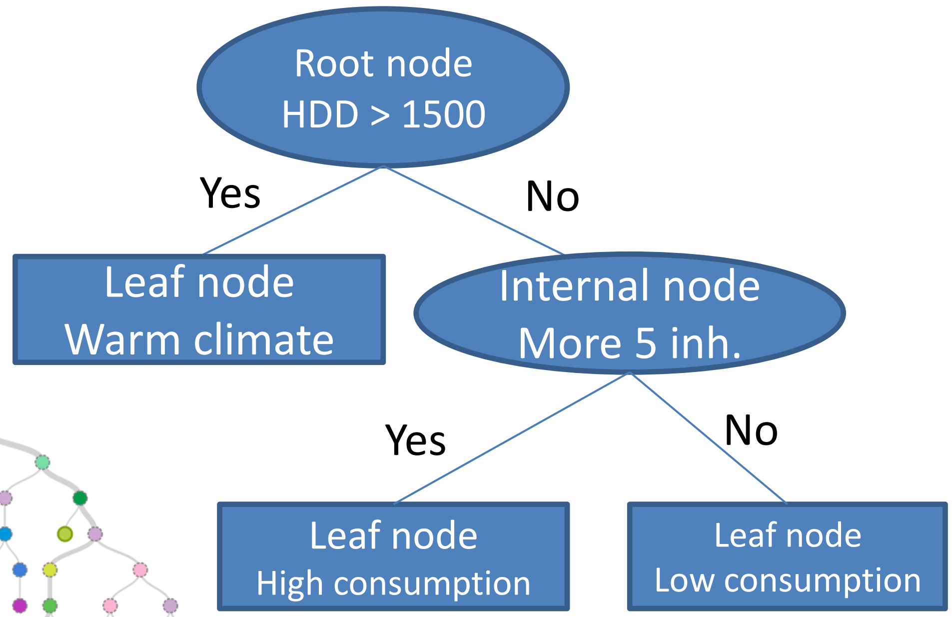
1. Overfitting
2. Underfitting

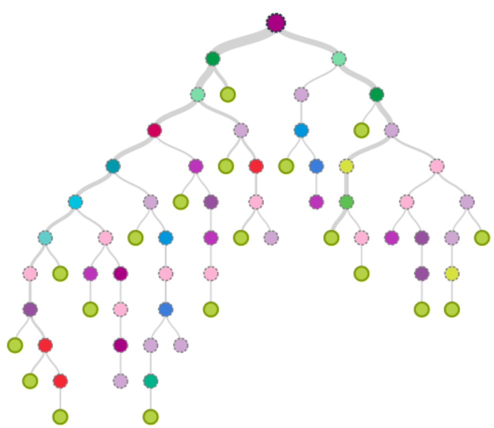


Source: graphic EnBW, VGB, www.vgb.org

Decission tree algorithm

Parameter	Type
Building envelope characteristics	Numerical
Heating degree days	Numerical
Number of occupants	Numerical
Schedule of space usage	Categorical
Energy source	Categorical
Building installation losses	Numerical
Position of an apartment	Categorical
Existance of individual metering	Categorical
Confort level in the apartment	Categorical
Rediness to pay	Categorical





Source: graphic EnBW, VGB, www.vgb.org

Growing a tree

ROOT NODE	1	Node number
	700	Number of data records
	0,9568	Entropy
	HCA installed?	Splitting test
INTERNAL NODE	3	Node number
	200	Number of data records
	0,8500	Entropy
	HDD > 1500	Splitting test
LEAF NODE	10	Node number
	96	Number of data records
	0,0000	Entropy
	E savings	Classification result
	LEAF	Notation if LEAF or STOP

Source: graphic EnBW, VGB, www.vgb.org

Why this algorithm?

- Popular for decission makers
- Core algorith is ID3 by J.R. Quinlan (held positions at the University of Sydney, University of Technology Sydney, and RAND Corporation)
- Offen it is referred to as a „greedy algorithm” – top-down, never goes back to consider previous node
- Uses Entropy and Information Gain to construct a decision tree
- Top-down from a root node and involves partitioning the data into subsets that contain instances with similar values (homogenous)
- ID3 algorithm uses entropy to calculate the homogeneity of a sample (completely homogenous = 0, sample equally devided = 1)

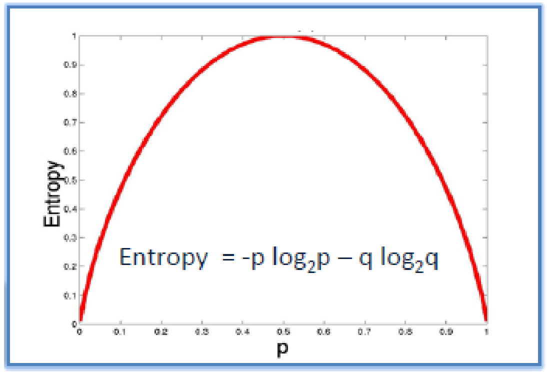
Choose the highest information gain

Have HCA?	
Yes	No
9	5

Entropy(HaveHCA) = Entropy(5,9)
= Entropy(0,36;0,64)
= - (0,36 $\log_2$0,36) – (0,64 $\log_2$0,64)
= 0,94

		Have HCA?	
		Yes	No
Schedule of use	<24h	3	2
	<12h	4	0
	<8h	2	3
Gain = 0,250			

Entropy(HaveHCA,Schedule) = P(<24h)*Entropy(3,2) + P(<12h)*Entropy(4,0) + P(<8h)*Entropy(2,3)
= (5/14)*0,971+(4/14)*0,0+(5/14)*0,971 = 0,693



Entropy = -0.5 $\log_2$0.5 – 0.5 $\log_2$0.5 = 1

		Have HCA?	
		Yes	No
Schedule of use	<24h	3	2
	<12h	4	0
	<8h	2	3
Gain = 0,250			

		Have HCA?	
		Yes	No
Number of occupants	1	2	2
	2	4	2
	>2	3	3
Gain = 0,031			

		Have HCA?	
		Yes	No
HDD	Yes	3	4
	No	6	2
Gain = 0,158			

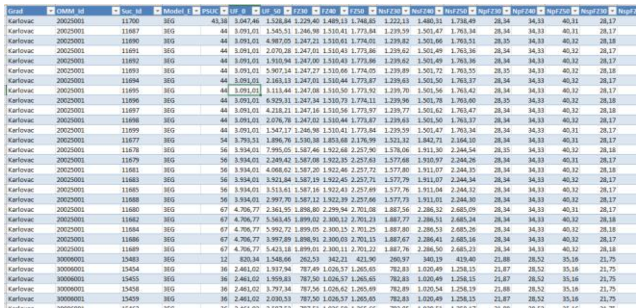
		Have HCA?	
		Yes	No
Position	Middle	2	6
	Edge	3	3
Gain = 0,051			

Gain(HaveHCA,X) = Entropy(HaveHCA) – Entropy(HaveHCA,X)

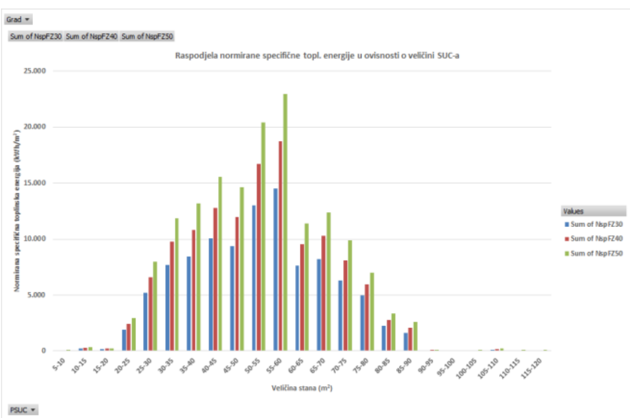
Choose the attribute with the biggest information gain as a root node.
Entropy 0 = leaf node. Entropy >0 needs more splitting – internal node.
Run until all data is classified.

Source: graphic EnBW, VGB, www.vgb.org

Present. Data collection.



Grad	OMM_Id	Suc_Id	Model_E	PSUC	UF_0	UF_50	FZ30	FZ40	FZ50	NsFZ30	NsFZ40	NsFZ50	NpFZ30	NpFZ40	NpFZ50	NspFZ30	NspFZ
Karlovac	20025001	11700	3EG	43,38	3.047,46	1.528,84	1.229,40	1.489,13	1.748,85	1.222,13	1.480,31	1.738,49	28,34	34,33	40,31	28,17	
Karlovac	20025001	11687	3EG	44	3.091,01	1.545,51	1.246,98	1.510,41	1.773,84	1.239,59	1.501,47	1.763,34	28,34	34,33	40,31	28,17	
Karlovac	20025001	11690	3EG	44	3.091,01	4.987,05	1.247,21	1.510,61	1.774,01	1.239,82	1.501,66	1.763,51	28,35	34,33	40,32	28,18	
Karlovac	20025001	11691	3EG	44	3.091,01	2.070,28	1.247,01	1.510,43	1.773,86	1.239,62	1.501,49	1.763,36	28,34	34,33	40,32	28,17	
Karlovac	20025001	11692	3EG	44	3.091,01	1.910,94	1.247,00	1.510,43	1.773,86	1.239,62	1.501,49	1.763,36	28,34	34,33	40,32	28,17	
Karlovac	20025001	11693	3EG	44	3.091,01	5.907,14	1.247,27	1.510,66	1.774,05	1.239,89	1.501,72	1.763,55	28,35	34,33	40,32	28,18	
Karlovac	20025001	11694	3EG	44	3.091,01	2.163,13	1.247,01	1.510,44	1.773,87	1.239,63	1.501,50	1.763,37	28,34	34,33	40,32	28,17	
Karlovac	20025001	11695	3EG	44	3.091,01	3.113,44	1.247,08	1.510,50	1.773,92	1.239,70	1.501,56	1.763,42	28,34	34,33	40,32	28,17	
Karlovac	20025001	11696	3EG	44	3.091,01	6.929,31	1.247,34	1.510,73	1.774,11	1.239,96	1.501,78	1.763,60	28,35	34,33	40,32	28,18	
Karlovac	20025001	11697	3EG	44	3.091,01	4.218,21	1.247,16	1.510,56	1.773,97	1.239,77	1.501,62	1.763,47	28,34	34,33	40,32	28,18	
Karlovac	20025001	11698	3EG	44	3.091,01	2.076,78	1.247,02	1.510,44	1.773,87	1.239,63	1.501,50	1.763,37	28,34	34,33	40,32	28,17	
Karlovac	20025001	11699	3EG	44	3.091,01	1.547,17	1.246,98	1.510,41	1.773,84	1.239,59	1.501,47	1.763,34	28,34	34,33	40,31	28,17	
Karlovac	20025001	11677	3EG	54	3.793,51	1.896,76	1.530,38	1.853,68	2.176,99	1.521,32	1.842,71	2.164,10	28,34	34,33	40,31	28,17	
Karlovac	20025001	11678	3EG	56	3.934,01	7.995,05	1.587,46	1.922,68	2.257,90	1.578,06	1.911,30	2.244,54	28,35	34,33	40,32	28,18	
Karlovac	20025001	11679	3EG	56	3.934,01	2.249,42	1.587,08	1.922,35	2.257,63	1.577,68	1.910,97	2.244,26	28,34	34,33	40,31	28,17	
Karlovac	20025001	11681	3EG	56	3.934,01	4.068,62	1.587,20	1.922,46	2.257,72	1.577,80	1.911,07	2.244,35	28,34	34,33	40,32	28,18	
Karlovac	20025001	11683	3EG	56	3.934,01	3.921,84	1.587,19	1.922,45	2.257,71	1.577,79	1.911,07	2.244,34	28,34	34,33	40,32	28,17	
Karlovac	20025001	11685	3EG	56	3.934,01	3.513,61	1.587,16	1.922,43	2.257,69	1.577,76	1.911,04	2.244,32	28,34	34,33	40,32	28,17	
Karlovac	20025001	11688	3EG	56	3.934,01	2.997,70	1.587,12	1.922,39	2.257,66	1.577,73	1.911,01	2.244,30	28,34	34,33	40,32	28,17	
Karlovac	20025001	11680	3EG	67	4.706,77	2.361,95	1.898,80	2.299,94	2.701,08	1.887,56	2.286,32	2.685,09	28,34	34,33	40,31	28,17	
Karlovac	20025001	11682	3EG	67	4.706,77	5.563,45	1.899,02	2.300,12	2.701,23	1.887,77	2.286,51	2.685,24	28,34	34,33	40,32	28,18	
Karlovac	20025001	11684	3EG	67	4.706,77	5.992,72	1.899,05	2.300,15	2.701,25	1.887,80	2.286,53	2.685,26	28,34	34,33	40,32	28,18	
Karlovac	20025001	11686	3EG	67	4.706,77	3.997,89	1.898,91	2.300,03	2.701,15	1.887,67	2.286,41	2.685,16	28,34	34,33	40,32	28,17	
Karlovac	20025001	11689	3EG	67	4.706,77	5.423,18	1.899,01	2.300,11	2.701,22	1.887,76	2.286,50	2.685,23	28,34	34,33	40,32	28,18	
Karlovac	30006001	15483	3EG	12	820,34	1.548,66	262,53	342,21	421,90	260,97	340,19	419,40	21,88	28,52	35,16	21,75	
Karlovac	30006001	15454	3EG	36	2.461,02	1.937,94	787,49	1.026,57	1.265,65	782,83	1.020,49	1.258,15	21,87	28,52	35,16	21,75	
Karlovac	30006001	15455	3EG	36	2.461,02	1.959,83	787,50	1.026,57	1.265,65	782,83	1.020,49	1.258,15	21,87	28,52	35,16	21,75	
Karlovac	30006001	15458	3EG	36	2.461,02	3.797,34	787,56	1.026,62	1.265,69	782,89	1.020,54	1.258,19	21,88	28,52	35,16	21,75	
Karlovac	30006001	15459	3EG	36	2.461,02	2.030,53	787,50	1.026,57	1.265,65	782,83	1.020,49	1.258,15	21,87	28,52	35,16	21,75	
Karlovac	30006001	15462	3EG	36	2.461,02	2.597,53	787,51	1.026,59	1.265,66	782,85	1.020,51	1.258,17	21,88	28,52	35,16	21,75	



- Having data for 50 buildings in mentioned cities (app. 3600 apartments)
- Make questionnaires for the existing building set
- Run ID3 algorithm
- Target – get energy data for all DH in Croatia (end 2016)
- Consider other algorithms – Bayesian Classifier

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Thank you for your attention

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Danica Maljković

Energy Institute Hrvoje Požar

Savska cesta 163, Zagreb, Croatia

T: + 385 1 6326 166

F: + 385 1 6040 599

dmaljkovic@eihp.hr

www.eihp.hr

AALBORG UNIVERSITY
DENMARK