

Energy optimization without affecting comfort



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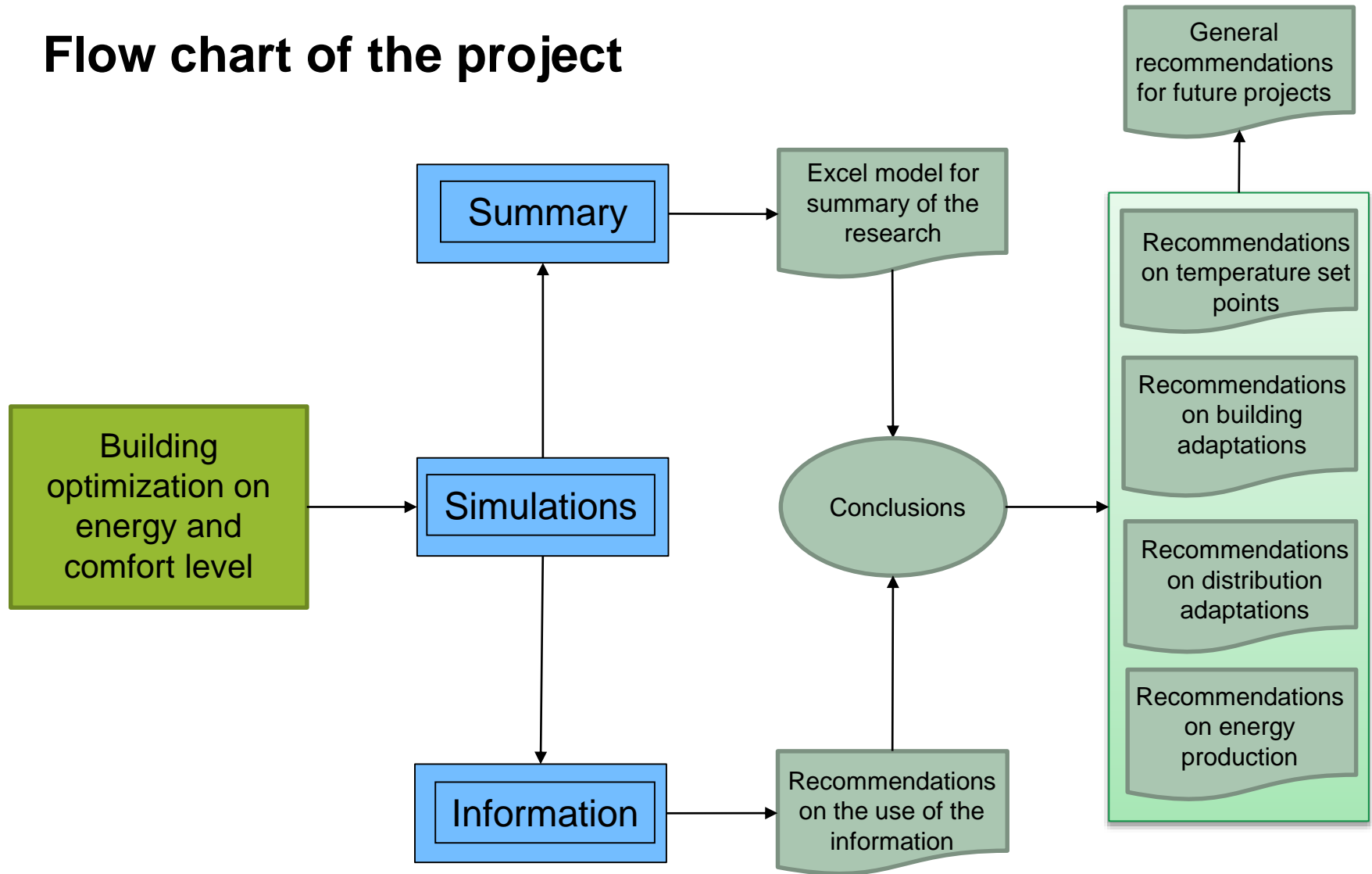
Arch. Markus Kalo, M.Sc.

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- Introduction: Goal of the project
- Analysis and methods
- Results
- Conclusions
- Recommendations
 - Recommendations for new office building in Kvänum
 - General recommendations

Flow chart of the project



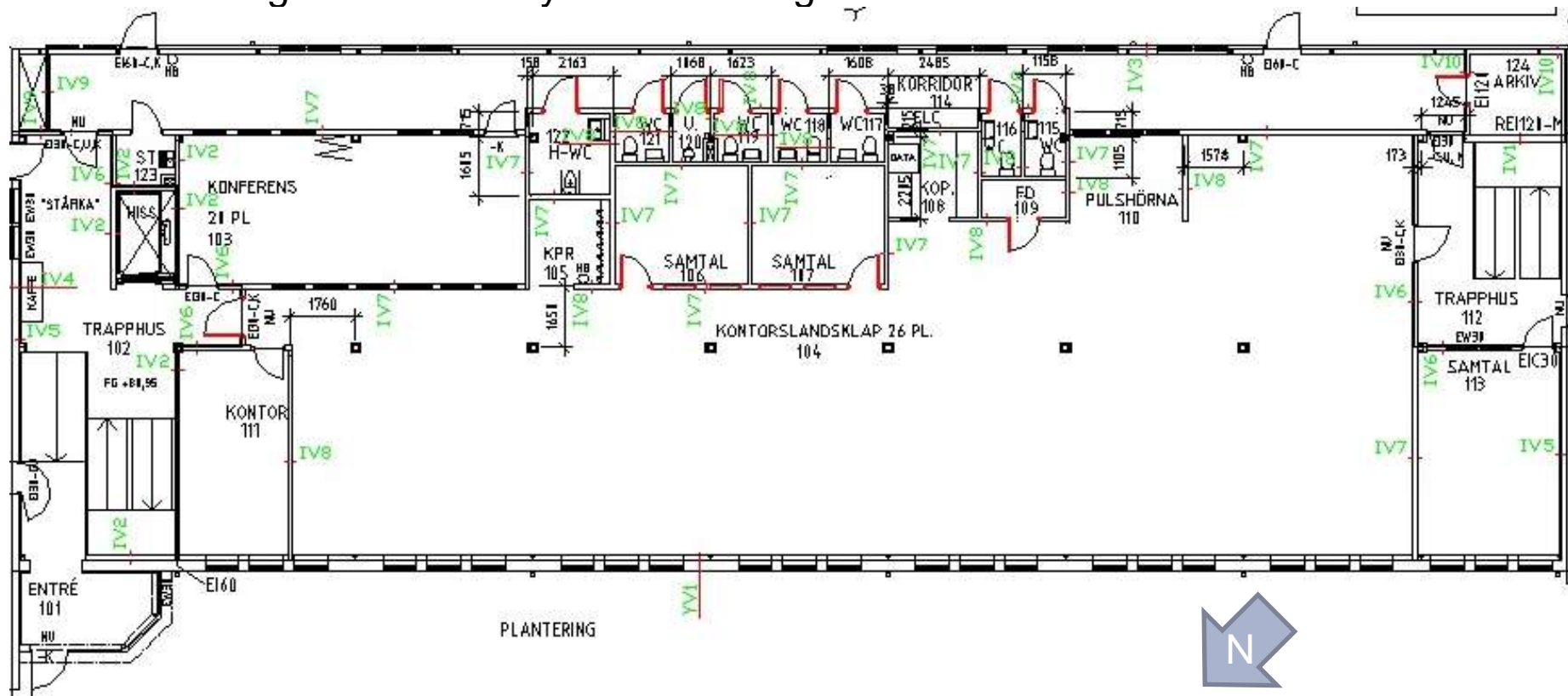
Reasons for optimization of climate and energy

- People spent 90% of their time indoors, good indoor climate is important
- Best indoor climate is the healthiest for its users
- Higher productivity, lower sickness
 - Source: Best in class – Svensk Ventilation
- Indoor climate: PMV-PPD model by Fanger (EN 15251)

Class	Comfort Indices		Operative Temperatures (°C)		Airflow		CO ₂ levels (ppm)	
	PPD (%)	PMV	Minimum	Maximum	Per person (l/s)	Per m ² (l/s/m ²)	Above outdoors	Maximum indoors
I	< 6	-0,2 / +0,2	21	25,5	10	0,5	350	750
II	< 10	-0,5 / +0,5	20	26	7	0,35	500	900
III	< 15	-0,7 / +0,7	19	27	4	0,2	800	1 200
IV	> 15	< -0,7 / +0,7 >	N.A.	N.A.	< 4	N.A.	< 800	< 1 200

Building data

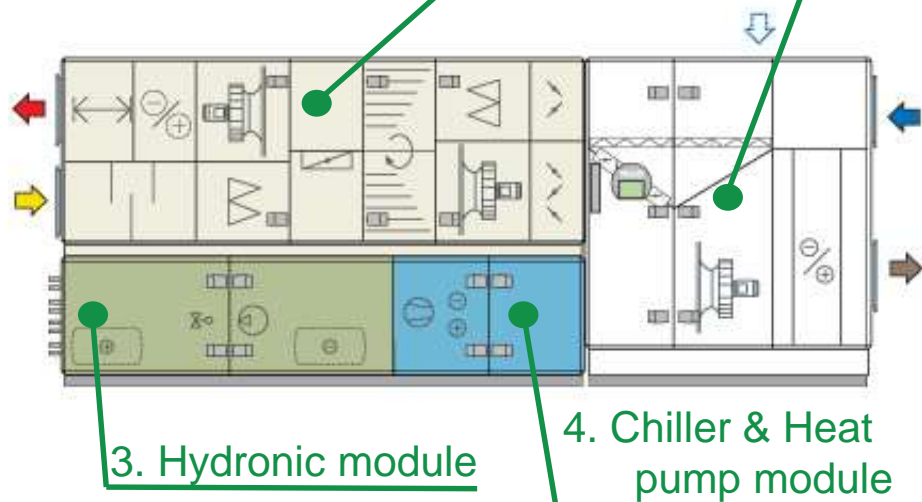
- Floor area of 1 690 m², 3 floors, built in 2012, 75 occupants in total
- Building is enclosed by other buildings on different floor levels



Installation data

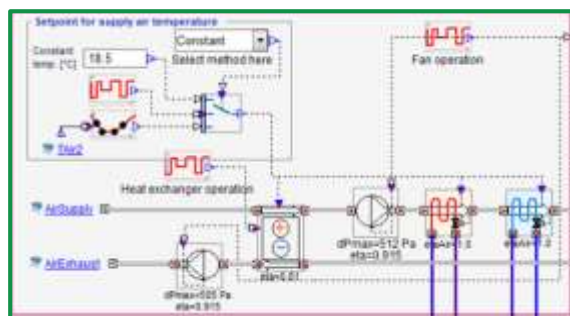
2. Energy Exchange module

1. Air Handling module

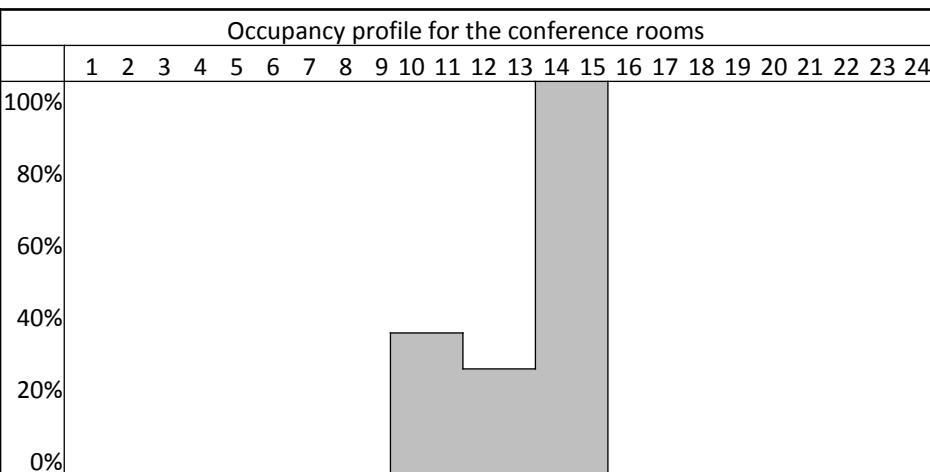
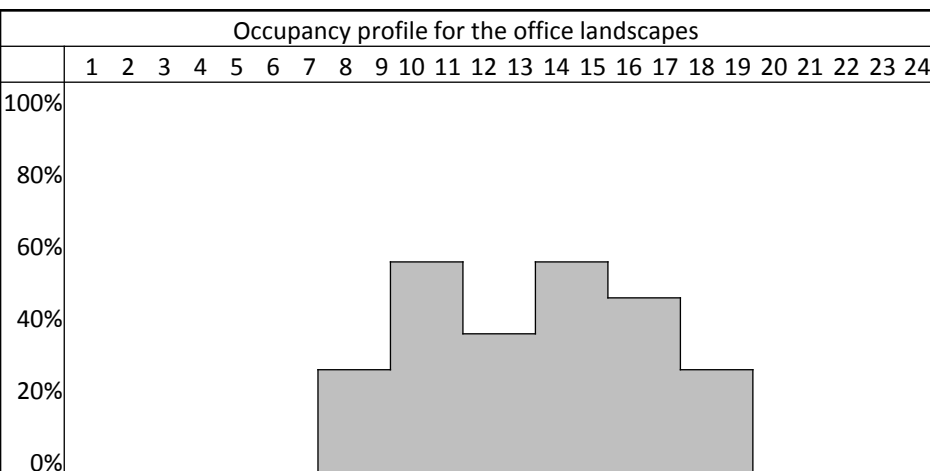


Multifunctional unit consists of:

1. Air handling unit, for supplying and extracting air, only component in IDA ICE (shown below)
2. EE module, extra coil as condenser in the summer and evaporator in winter
3. Hydronic module to facilitate cold and hot water for heating, cooling, tap water
4. Chiller module for producing hot and cold water



Occupancy data



- Profile for office landscapes with 25 persons
- More gradual internal load throughout the day
- Average occupancy between 30% - 50%
- Profile for conference rooms with 1 person per 1,5 m² → 15 – 25 persons
- Higher internal load for short time
- High peak in occupancy in the afternoon
- Also takes external persons into account

Calculation data

- Dynamic energy simulations done with IDA ICE software
- Efficiency and prices based on IDA ICE and online research
- Additional electrical energy consumptions added in Excel model for more accurate total energy consumption

Prices in EUR		
Electricity	0,13	EUR
District heating	0,09	EUR
District cooling	0,11	EUR
Oil	0,10	EUR
Gas	0,09	EUR

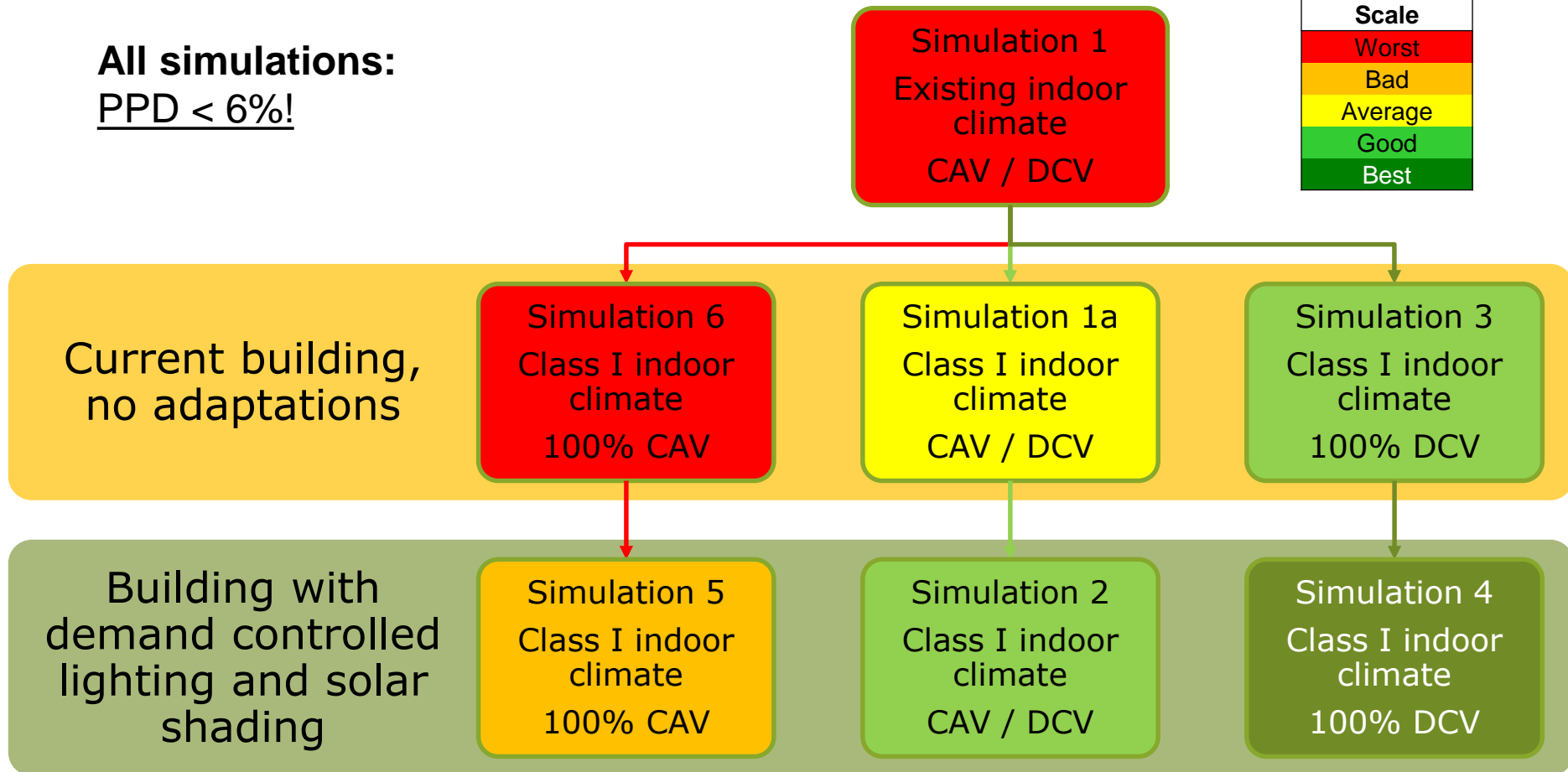
Efficiency	
EER cooling	3,0
COP heating	4,0
Electricity	1,0
District heating	1,0
District cooling	1,0
Oil	0,9
Gas	0,9



The adaptations

All simulations:
PPD < 6%!

Scale
Worst
Bad
Average
Good
Best



Results of the simulations

- All numbers (except months) are in kWh

Simulation 1, current building with CAV / DCV, no adaptations								
Month	Zone heating	Zone cooling	AHU heating	AHU cooling	purchased energy Swedish model (buy cooling)		Heating energy saved	total
1	8 322	110	889	769	2 010	293	293	2 303
2	6 709	122	982	650	1 665	258	258	1 923
3	5 292	156	63	965	965	374	374	1 339
4	2 611	184	27	1 066	243	417	417	660
5	620	283	0	1 589	0	624	155	624
6	62	457	0	2 327	0	928	16	928
7	0	955	0	4 568	0	1 841	0	1 841
8	78	502	0	4 054	0	1 519	19	1 519
9	1 290	224	0	1 263	0	496	323	496
10	3 693	175	0	1 105	497	427	427	923
11	6 490	116	93	944	1 293	353	353	1 646
12	9 096	93	2 154	713	2 544	269	269	2 813
Total	44 263	3 375	4 208	20 013	9 216	7 796	2 901	17 012

Total purchased energy for multifunctional unit
33 724 kWh / year

Lighting
27 312 kWh / year

Equipment
10 766 kWh / year

Building services
44 049 kWh / year

Total:
115 851 kWh / year

Explanation of the main table

- Excel model automatically reacts to new results
- Excel model shows best to worst results in color

Efficiency		
1,00	worst	1,82
1,82	bad	2,64
2,64	average	3,46
3,46	good	4,27
4,27	best	5,09

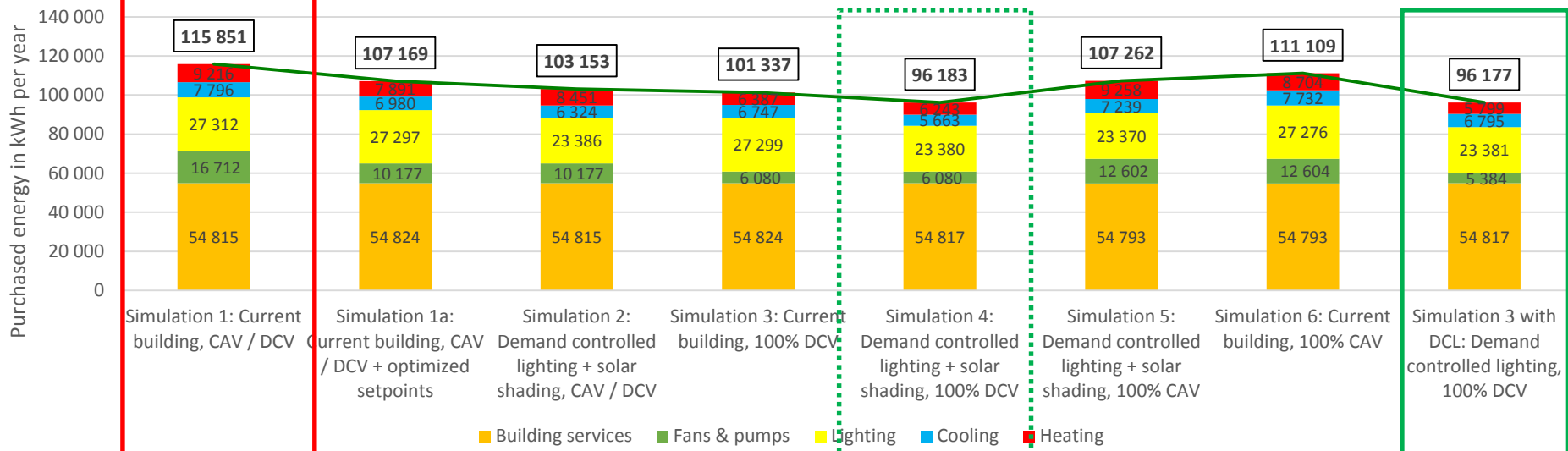
Total cost in Euro		
20 164	worst	18 603
18 603	bad	17 042
17 042	average	15 482
15 482	good	13 921
13 921	best	12 360

Purchased energy / m ²		
101,03	worst	92,08
92,08	bad	83,13
83,13	average	74,18
74,18	good	65,22
65,22	best	56,27

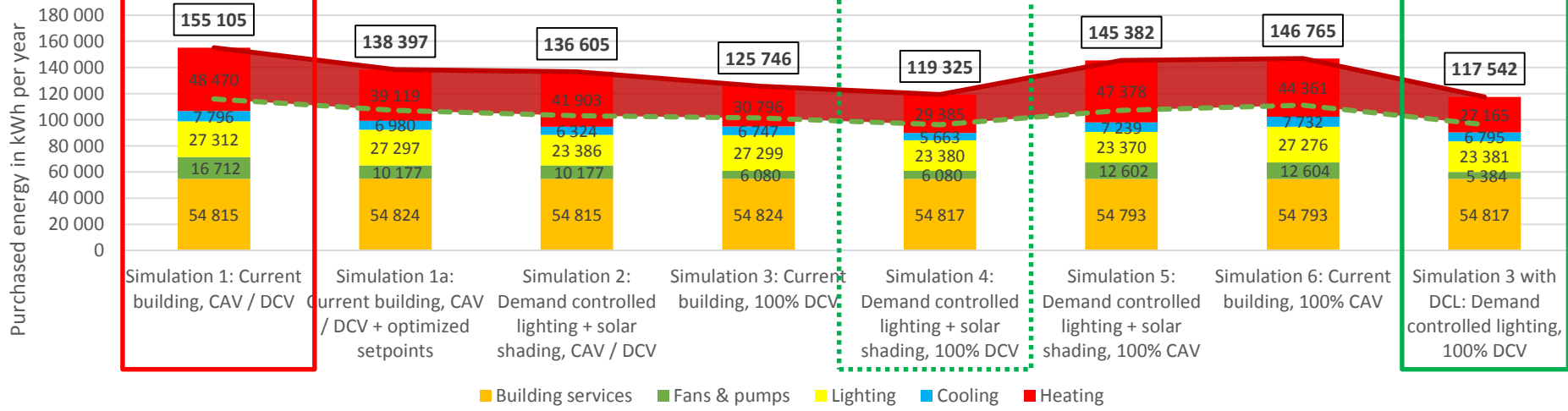
Introduction		Analysis and methods			Results		Conclusions		Recommendations
Heating and cooling system used in each method		Simulation 1	Simulation 1a	Simulation 2	Simulation 3	Simulation 4	Simulation 5	Simulation 6	
		Current building Existing DCV	Sim. 1 + Optimized setpoints	Improved building Existing DCV	Current building 100% DCV	Improved building 100% DCV	Improved building 100% CAV	Current building 100% CAV	
A	Multifunctional unit	5,09	4,63	4,77	4,32	4,29	4,97	4,81	Efficiency
		15 061EUR	13 932EUR	13 410EUR	13 174EUR	12 504EUR	13 944EUR	14 444EUR	Operating Cost / year
		66,85kWh/m ²	62,31kWh/m ²	59,85kWh/m ²	59,20kWh/m ²	56,27kWh/m ²	61,95kWh/m ²	64,35kWh/m ²	Purchased energy / m ²
B	AHU Chiller District heating	1,28	1,30	1,26	1,36	1,32	1,27	1,30	Efficiency
		18 225EUR	16 427EUR	16 082EUR	15 115EUR	14 337EUR	17 005EUR	17 305EUR	Operating Cost / year
		91,80kWh/m ²	81,91kWh/m ²	80,85kWh/m ²	74,42kWh/m ²	70,62kWh/m ²	86,05kWh/m ²	86,86kWh/m ²	Purchased energy / m ²
C	AHU Chiller Heat pump	3,61	3,58	3,62	3,53	3,56	3,62	3,59	Efficiency
		15 438EUR	14 178EUR	13 673EUR	13 344EUR	12 647EUR	14 280EUR	14 754EUR	Operating Cost / year
		70,28kWh/m ²	64,55kWh/m ²	62,25kWh/m ²	60,75kWh/m ²	57,58kWh/m ²	65,01kWh/m ²	67,17kWh/m ²	Purchased energy / m ²
D	AHU Chiller Direct Electricity	1,28	1,30	1,26	1,36	1,32	1,27	1,30	Efficiency
		20 164EUR	17 992EUR	17 759EUR	16 347EUR	15 512EUR	18 900EUR	19 080EUR	Operating Cost / year
		91,80kWh/m ²	81,91kWh/m ²	80,85kWh/m ²	74,42kWh/m ²	70,62kWh/m ²	86,05kWh/m ²	86,86kWh/m ²	Purchased energy / m ²
E	AHU Chiller Oil	1,17	1,19	1,15	1,25	1,21	1,15	1,18	Efficiency
		19 248EUR	17 253EUR	16 967EUR	15 765EUR	14 957EUR	18 005EUR	18 242EUR	Operating Cost / year
		94,99kWh/m ²	84,48kWh/m ²	83,61kWh/m ²	76,45kWh/m ²	72,56kWh/m ²	89,16kWh/m ²	89,78kWh/m ²	Purchased energy / m ²
F	AHU Chiller Gas	1,17	1,19	1,15	1,25	1,21	1,15	1,18	Efficiency
		18 710EUR	16 818EUR	16 502EUR	15 423EUR	14 631EUR	17 478EUR	17 749EUR	Operating Cost / year
		94,99kWh/m ²	84,48kWh/m ²	83,61kWh/m ²	76,45kWh/m ²	72,56kWh/m ²	89,16kWh/m ²	89,78kWh/m ²	Purchased energy / m ²
G	AHU District cooling District heating	1,00	1,00	1,00	1,00	1,00	1,00	1,00	Efficiency
		19 784EUR	17 823EUR	17 347EUR	16 465EUR	15 469EUR	18 452EUR	18 851EUR	Operating Cost / year
		101,03kWh/m ²	90,17kWh/m ²	88,34kWh/m ²	82,41kWh/m ²	77,33kWh/m ²	94,61kWh/m ²	96,02kWh/m ²	Purchased energy / m ²

		Simulation 1 Current building Existing DCV	Simulation 3 Current building 100% DCV	Simulation 4 Improved building 100% DCV	
A	Multifunctional unit	5,09	4,32	4,29	Efficiency
		15 061 EUR	13 174 EUR	12 504 EUR	Operating Cost / year
		66,85 kWh/m ²	59,20 kWh/m ²	56,27 kWh/m ²	Purchased energy / m ² / year
B	AHU	1,28	1,36	1,32	Efficiency
	Chiller	18 225 EUR	15 115 EUR	14 337 EUR	Operating Cost / year
	District heating	91,80 kWh/m ²	74,42 kWh/m ²	70,62 kWh/m ²	Purchased energy / m ² / year
Difference between production method A and B		3 542 EUR	2 112 EUR	1 977 EUR	Operating Cost / year
		0%	13%	17%	Savings
		24,95 kWh/m ²	15,22 kWh/m ²	14,35 kWh/m ²	Purchased energy / m ² / year

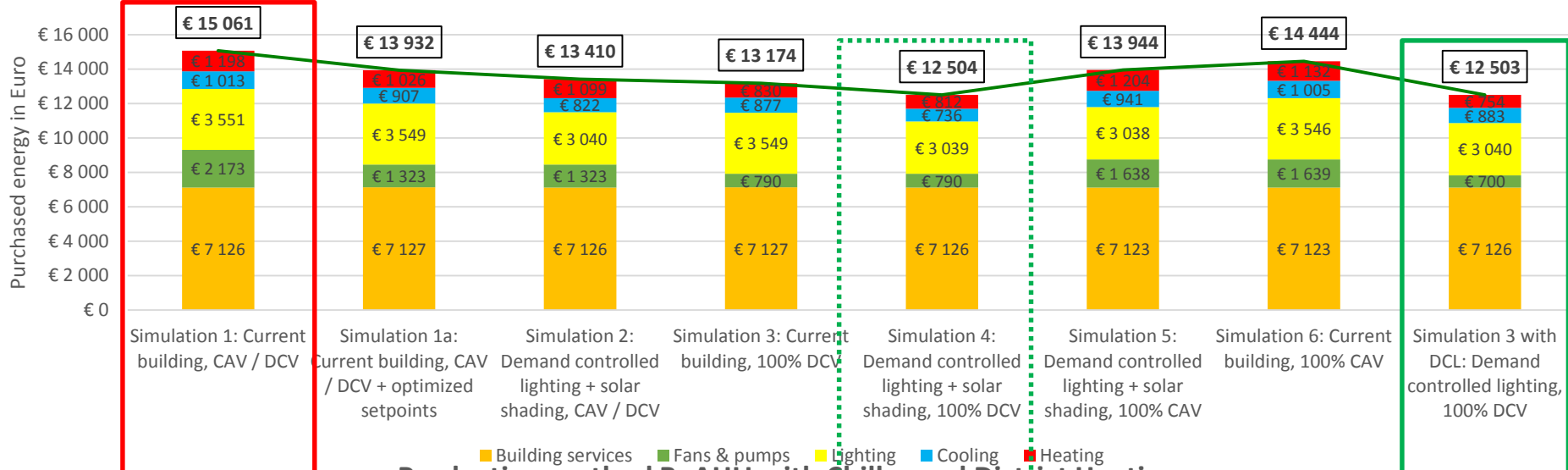
Production method A: Multifunctional unit



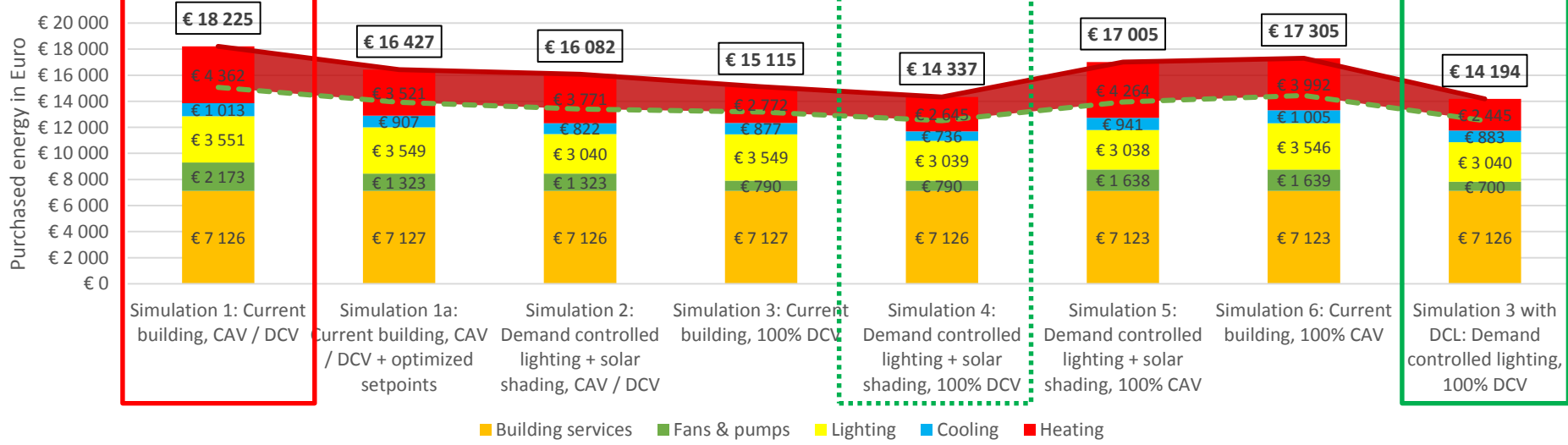
Production method B: AHU with Chiller and District Heating



Production method A: Multifunctional unit



Production method B: AHU with Chiller and District Heating



Building services Fans & pumps Lighting Cooling Heating

Best simulation: Building with demand controlled lighting and 100% DCV

- **Class I, best comfort achieved in all simulations, PPD < 6%!**
- Optimized temperature set points and minimum night time ventilation in simulation 1a saves 8 676 kWh/year = 1 129 €/year (7,5%)
 - 100% DCV in simulations 3, 4 save 5 833 kWh/year = 758 €/year (5%)
 - Demand controlled lighting in simulations 2, 4, 5 save 3 926 kWh/year = 510 €/year (3,4%)

All adaptations combined save: 18 441 kWh/year = 2 397 €/year (15,9%)

Best energy production method: Multifunctional unit

- Highest energy production efficiency / COP (5,09 – 4,29)
- Lowest operating cost per year (15 061 €/year – 12 360 €/year)
- Compared to the most common energy production method in Sweden, energy production method B: AHU with chiller and district heating:
 - Saves up to **19% - 26%** on produced energy in building
 - Saves up to **13% - 18%** on operating cost of the building
- Compared to the second best method C: AHU with chiller and heat pump:
 - Saves up to **1% - 2,4%** on produced energy and operating costs
- Multifunctional unit is proven to be the best choice for this building → **Heating and cooling demand at the same time**

Recommendations for Kvänum office building: temperature set points, lighting, ventilation set points

- Fanger suggests 21°C to 25,5°C → 21°C to 23°C in Kvänum office
- Apply demand controlled lighting in conference rooms
- Minimum required ventilation seems high
 - Minimum of 252 l/s on first floor and 232 l/s on second floor
- Set points in Table 9-5 for 100% DCV on 3rd floor
 - Allows for less ventilation at night, more energy savings

Table 9-5: Recommended new set points for the third floor

Supply air	Supply
Airflow min occupied	178 l/s
Airflow max occupied	330 l/s
Airflow unoccupied	178 l/s

Old temperature set points	Occupied temperature		Unoccupied temperature	
	Cool	Heat	Cool	Heat
Type				
Office landscape	23°C	21°C	25°C	20°C
Conference rooms	22°C	21°C	24°C	21°C



New temperature set points	Occupied temperature		Unoccupied temperature	
	Cool	Heat	Cool	Heat
Type				
Office landscape	23°C	21°C	25°C	19°C
Conference rooms	23°C	21°C	25°C	19°C

General recommendations for future projects with multifunctional unit

- Minimum of one downsize on AHU is possible with good dimensioning in design phase
- Make sure that the set points in BMS guarantee 100% DCV!
 - Prevent too much night ventilation
- Only heat pump or chiller is needed with multifunctional unit, not 2 different systems
- Large fluctuations in occupancy make demand controlled lighting more worthwhile → conference rooms, toilet, kitchen, corridor
- Research possible temperature set points within the desired boundaries
- Rebuild the Excel model so dynamic simulations are not required for the same output

Table 9-1	Bengt Dahlgren AB		simulation	simulation	simulation	simulation	simulation	simulation	simulation
	calculated	measured	1	1a	2	3	4	5	6
Reference	calculated	measured	calculated	calculated	calculated	calculated	calculated	calculated	calculated
Heating	23	19	28	23	25	18	17	28	26
Cooling	11	6,6	14	12	11	12	10	13	14
Building services	19	14	35	31	31	31	29	33	33
Equipment	18	15	22	22	20	22	20	20	22
Total	71	55	100	89	87	84	76	93	95

Improving your indoor climate and energy use in one giant leap at the same time!

- **Best indoor climate guaranteed**
- **Possible saving of up to 16% on energy use**
- **Possible saving of 18 441 kWh per year**
- **Possible saving of 2 397 €/year**



Thank you for your time!