Hydronic College

IMI Hydronic Engineering

Energy consumption

ON/OFF vs Modulating control

Engineering GREAT Solutions

2nd International HVAC Conference

Professional Chamber of Mechanical Engineers, Montenegro

22-23 September 2016, Budva

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Introduction

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Comparison of energy consumption

ON/OFF vs Modulating control at the fancoil units

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System

Basic technical data

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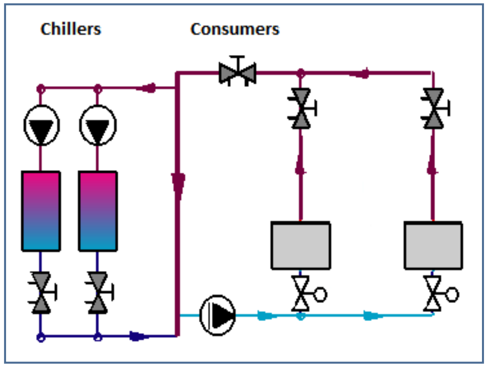
Office building (fictive) – cooling system

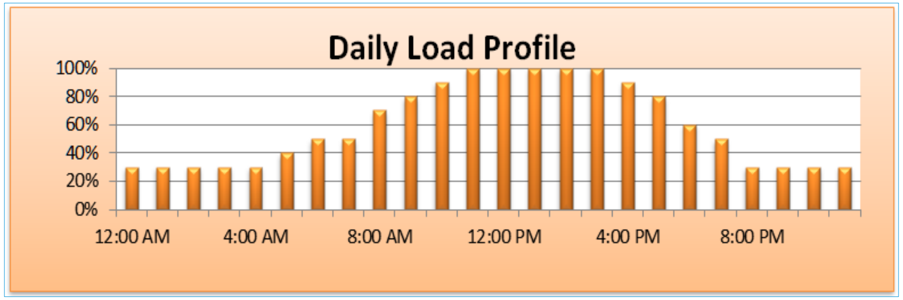
- **System:** air conditioning system (cooling side)
- **Building:** office building – ~ 10,000 m²
- **Cooling capacity:** 800 kW
- **Number of chillers:** 2 pcs
- **Type of chiller:** constant flow through evaporator
- **Type of the system:** cooling system with pressure break tank
- **Consumer system:** fan coils and AHU - variable flow system
  - power$_{fancoil}$: 60%
  - power$_{AHU}$: 40%
- **Temperature regime:** 7/12/24 °C; design outdoor temp.: 36 °C
- **Water flow rates and pump heads:**
  - fan coil: 480 kW; Δt=5K -> 82,500 l/h (H= 12 m)
  - AHU: 320 kW; Δt=5K -> 55,000 l/h (H= 15 m)
  - chillers (2): 400 kW/chiller -> 68,750 l/h (H= 10 m)



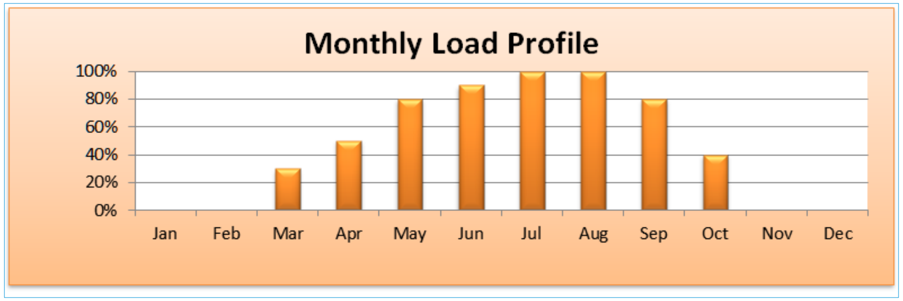
Price of electrical energy

- **Price of the electrical energy:** 0.18 EUR/kWh
- **Specific CO_2 emission:** 150 g/kWh

Load profiles



- **Daily load profile** (estimated)
  0:00 – 24:00



- **Monthly load profile** (estimated)

  January – December

- **Number of working days** (estimated)
  6 days/week

ON/OFF vs Modulating control

General information

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Modulating vs ON/OFF control

Imagine, the whole installation with **identical fancoils** actually operates at **50% of output power**.

The total system flow is*:

Modulating control	On-off control
~20%	~50%
All valves delivers 20% of flow	50% valves are fully open 50% valves are closed

*Using PIBCV valve

Room temperature – ON/OFF vs Modulating control

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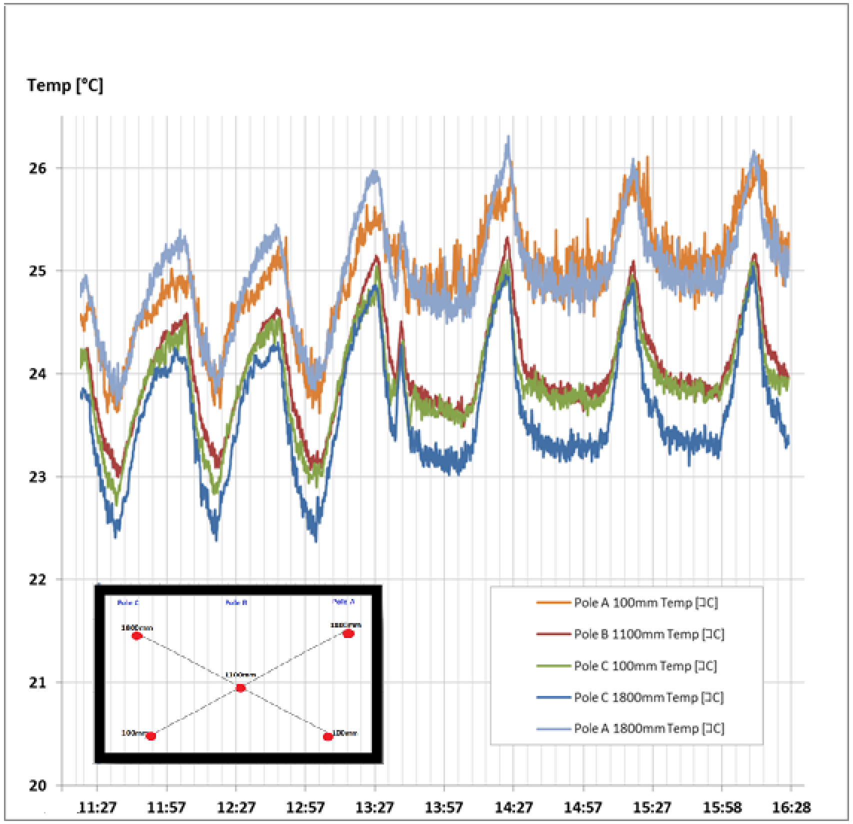
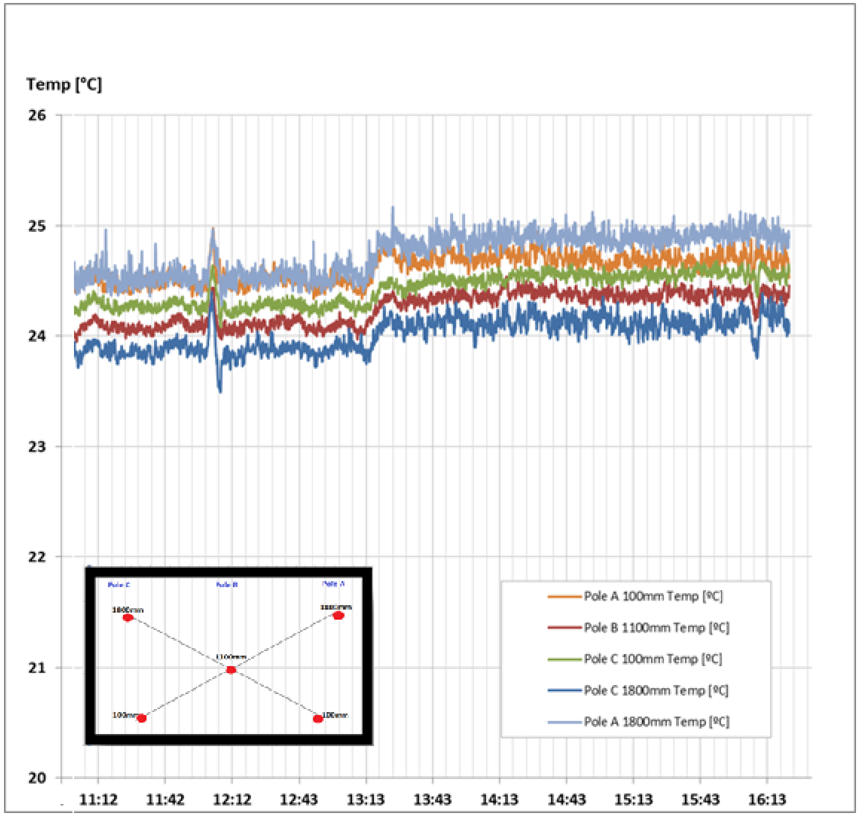
ON/OFF control



Modulating control



Modulating vs ON/OFF control

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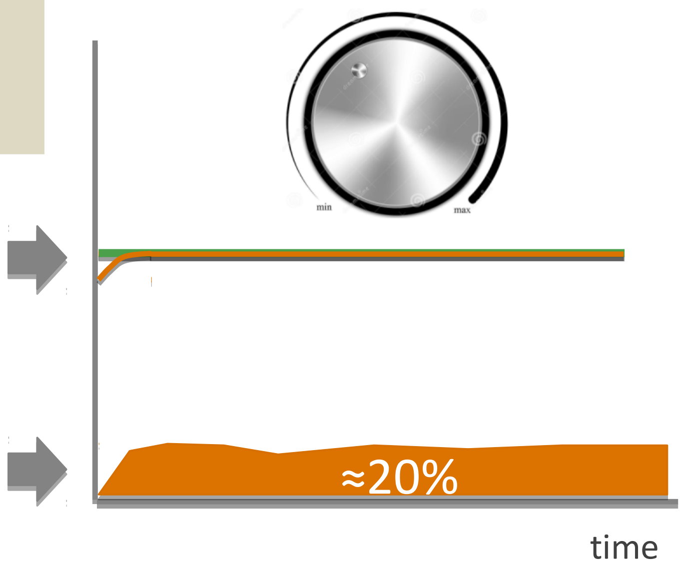
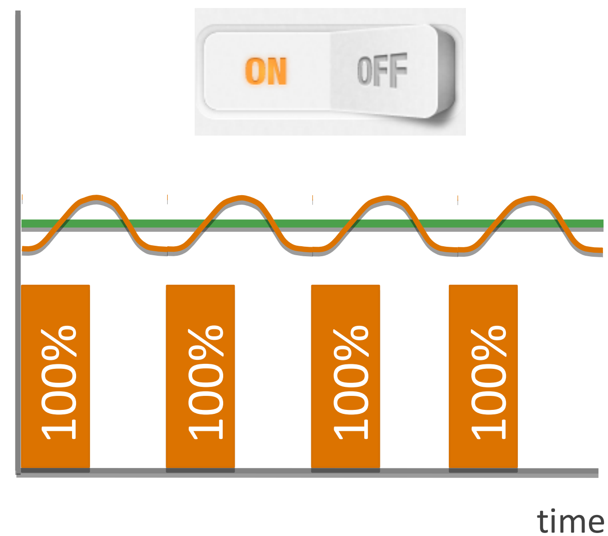
At **50%** of power demand

	Modulating control	On-off control
Desired temperature		
Flow		





	Modulating control	On-off control
Room temperature:	Stable, accurate	Oscilations
Flow rate:	Adequate to power	High/Zero
Pumping costs:	Low	Higher
Return temperature:	Ideal	Affected
Energy efficiency:	High	„Good“

Hydronic system

General information

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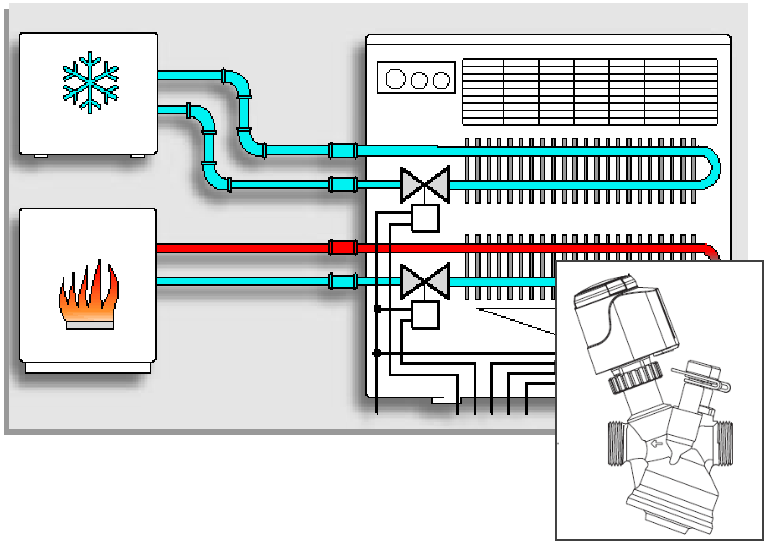
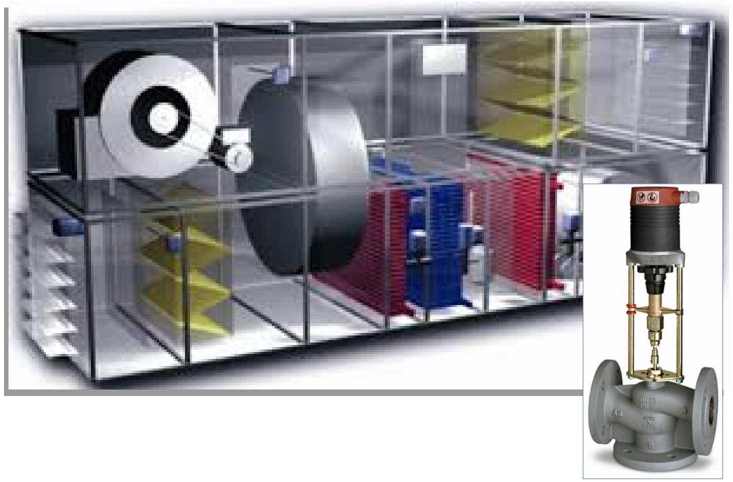
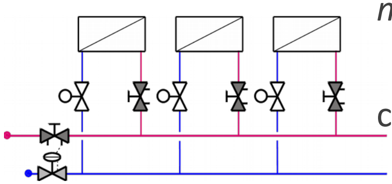
Solution A



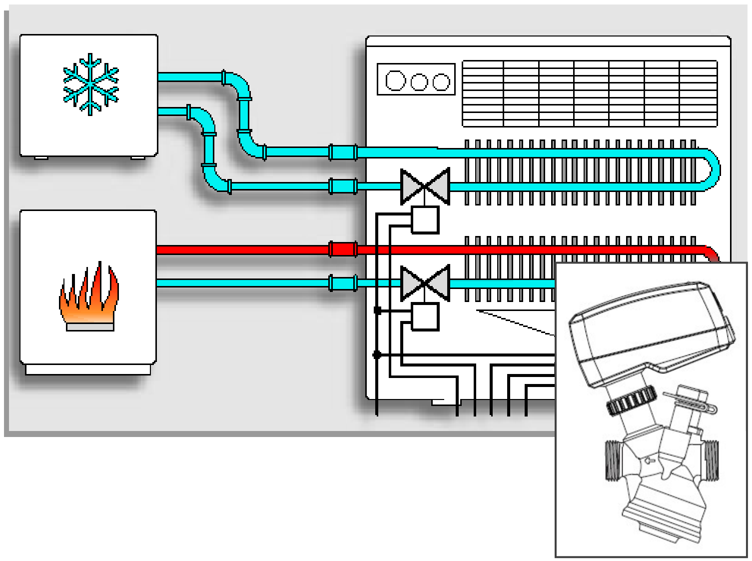
- **4-pipe fancoils (ON/OFF control):**
  - variable flow system
  - TA-Compact-P two-way control valve
    - linear valve characteristic
    - linear lift limitation
    - Δp stabilization: PIBCV
    - EMO-T actuator for ON/OFF control





- **AHU (modulating control 1):**
  - variable flow system
  - CV 216 GG two-way control valve
    - EQM valve characteristic
    - *Δp stabilization: pressure independent modules* (min. authority 0.25)
    - MC 100 actuator for modulating control

Solution B



- **4-pipe fancoils (modulating control):**
  - variable flow system
  - TA-Modulator two-way control valve
    - EQM valve characteristic
    - exponential lift limitation
    - Δp stabilization: PIBCV
    - TA-Slider 160 actuator for modulating control
- **AHU (modulating control 2):**
  - variable flow system
  - TA-Fusion-P two-way control valve
    - EQM valve characteristic
    - *Δp stabilization: PIBCV*
    - TA-Slider 750 actuator for modulating control

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Energy Insights Calculator

Basic information

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Energy Insights Calculator

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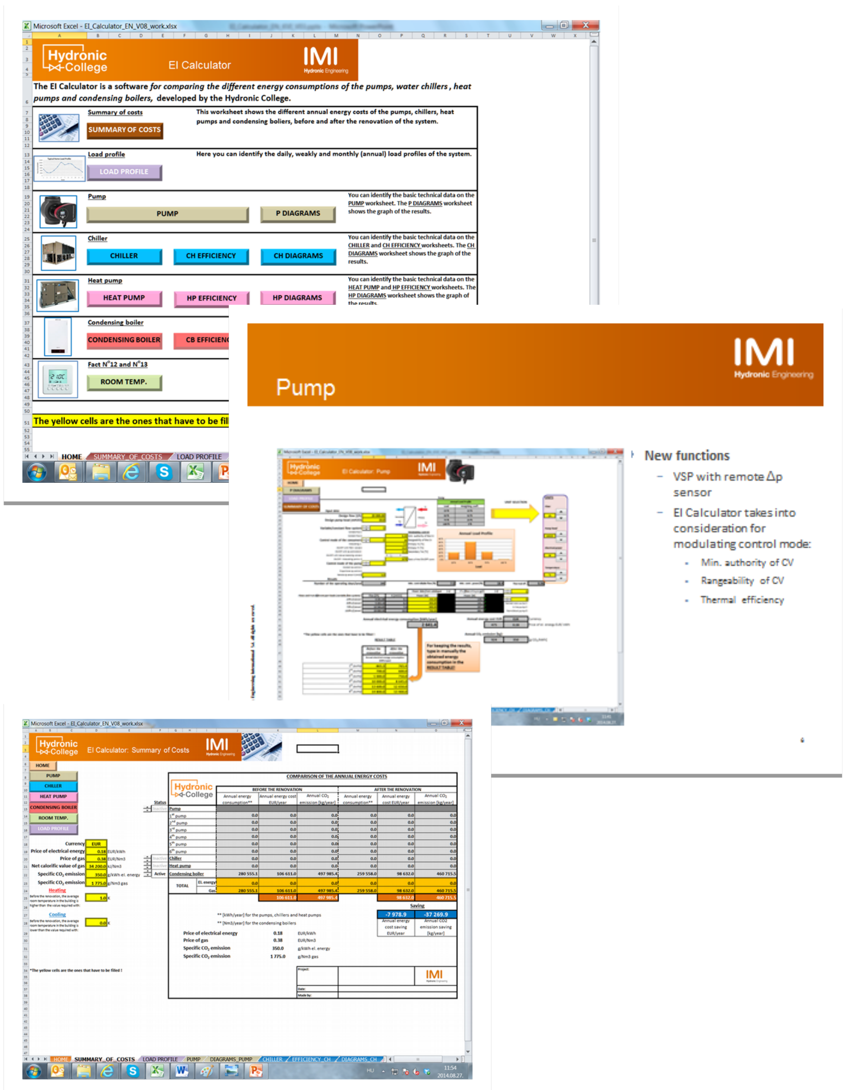

- **The Energy Insights Calculator** is a software **for comparing the different energy consumptions** of the
  - **pumps,**
  - **water chillers,**
  - **heat pumps and**
  - **condensing boilers.**
- This software can be used to present the **difference between the energy consumption** of the pumps, water chillers, heat pumps and condensing boilers which are **installed and operated at different conditions.**
- Developed by the **Hydronic College.**

Results

Energy Insights Calculator

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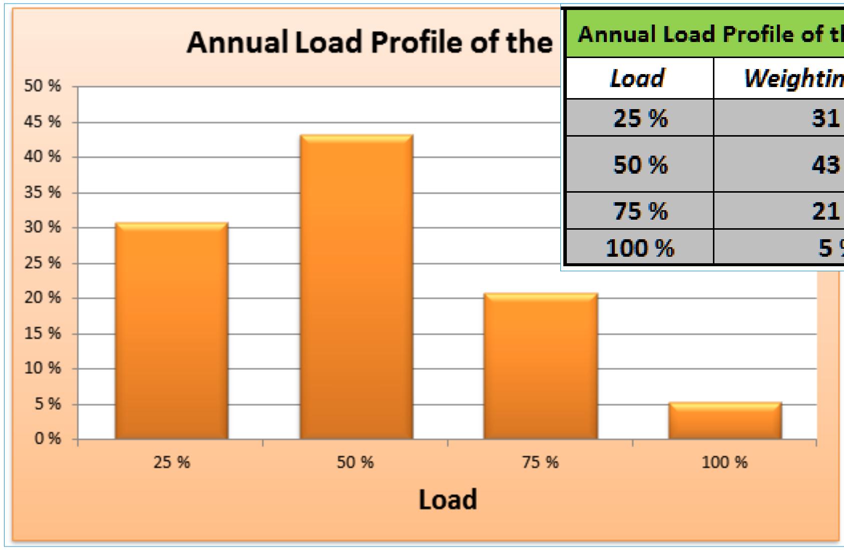
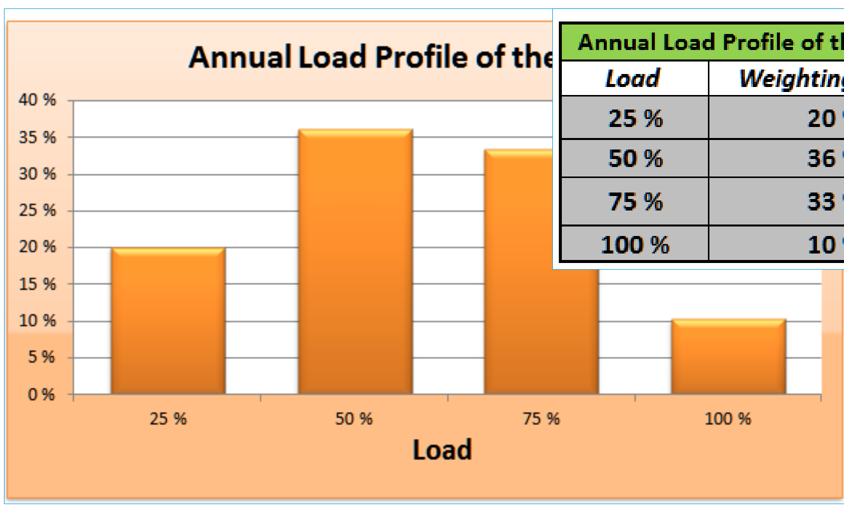
Annual load profile



Annual Load Profile of the System	
Load	*Weighting coeff.*
25 %	31 %
50 %	43 %
75 %	21 %
100 %	5 %

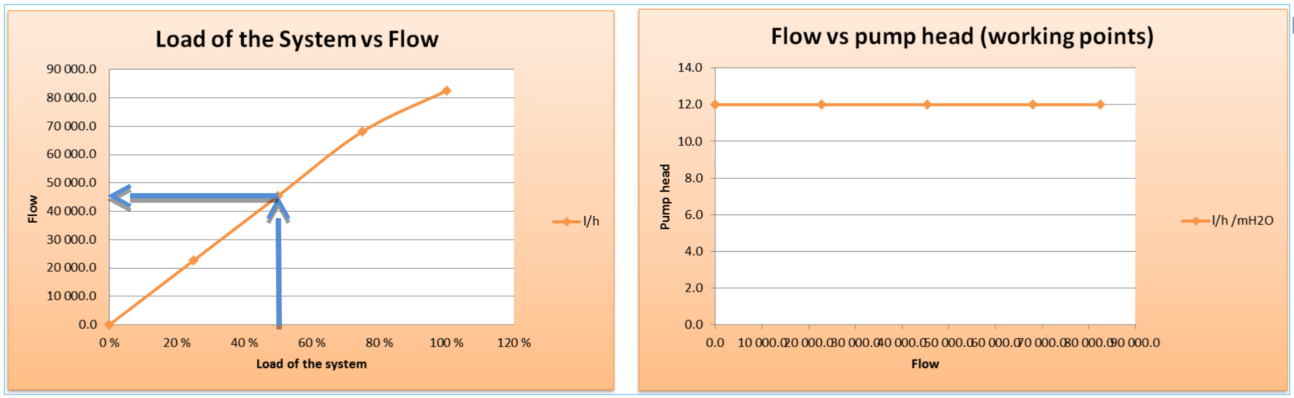
- **Annual Load profile of the <u>system</u>**
  - working days: 210 days



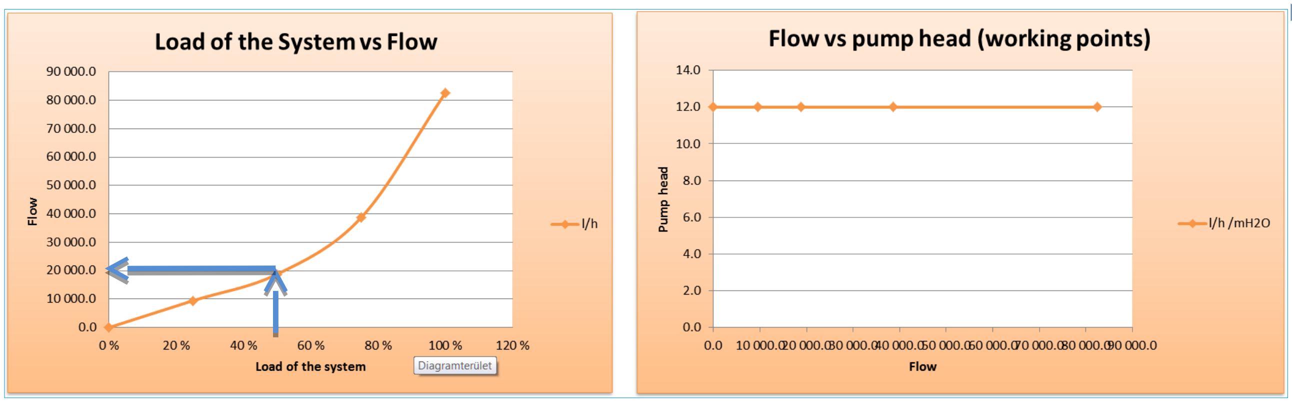
Annual Load Profile of the Chiller	
Load	*Weighting coeff.*
25 %	20 %
50 %	36 %
75 %	33 %
100 %	10 %

- **Annual Load profile of the <u>chillers</u>**
  - working days: 107 days/chiller

Pumping curves – fan coil system



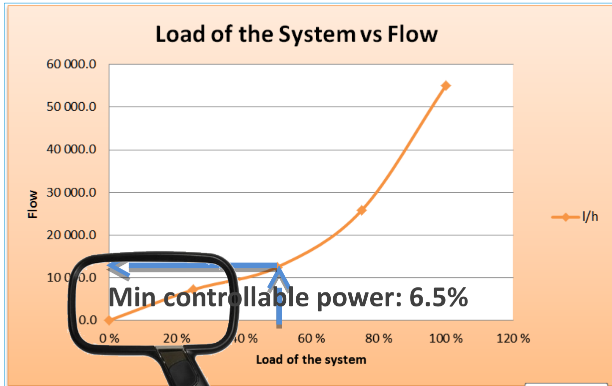
50% of load ➔ 45,000 l/h

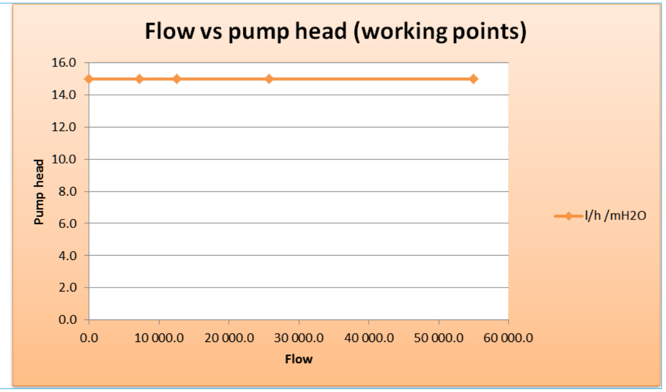


50% of load ➔ 20,000 l/h

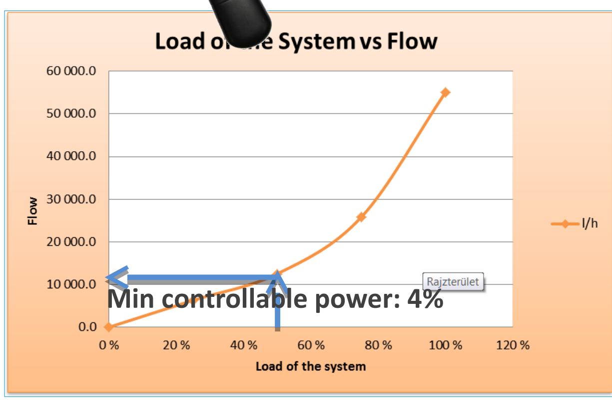
- **Solution A ON/OFF control**
  - Δp stabilization: PIBCV
  - VSP: constant Δp control
- **Solution B Modulating control**
  - Δp stabilization: PIBCV
  - VSP: constant Δp control

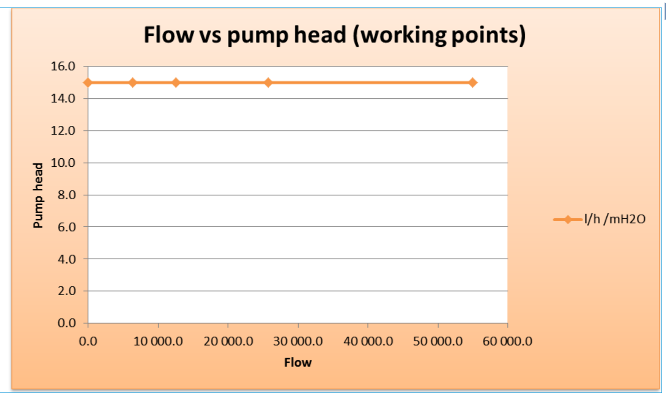
Pumping curves – AHU system





50% of load ➔ 12,500 l/h





50% of load ➔ 12,500 l/h

- **Solution A**
  Modulating control 1
  - Δp stabilization: pressure independent modules
  - VSP: constant Δp control
- **Solution B**
  Modulating control 2
  - Δp stabilization: PIBCV
  - VSP: constant Δp control

Pumping energy saving

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COMPARISON OF THE ANNUAL ENERGY COSTS

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	Solution A			Solution B		
	Annual energy consumption**	Annual energy cost EUR/year	Annual CO_2 emission [kg/year]	Annual energy consumption**	Annual energy cost EUR/year	Annual CO_2 emission [kg/year]
Pump						
Fan coil	13 878.0	2 498.0	2 081.7	6 998.0	1 259.6	1 049.7
AHU	5 960.0	1 072.8	894.0	5 831.0	1 049.6	874.7
Chiller 1	7 401.0	1 332.2	1 110.2	7 401.0	1 332.2	1 110.2
Chiller 2	7 401.0	1 332.2	1 110.2	7 401.0	1 332.2	1 110.2
	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
Chiller	0.0	0.0	0.0	0.0	0.0	0.0
Heat pump	0.0	0.0	0.0	0.0	0.0	0.0
Condensing boiler	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL El. energy	34 640.0	6 235.2	5 196.0	27 631.0	4 973.6	4 144.7
TOTAL Gas	0.0	0.0	0.0	0.0	0.0	0.0
		6 235.2	5 196.0		4 973.6	4 144.7

Saving

Annual energy cost saving EUR/year	Annual CO2 emission saving [kg/year]
-1 261.6	-1 051.4

** [kWh/year] for the pumps, chillers and heat pumps

** [m3/year] for the condensing boilers

Price of electrical energy	0.18	EUR/kWh
Price of gas	0.00	EUR/m3
Specific CO_2 emission	150.0	g/kWh el. energy
Specific CO_2 emission	0.0	g/m3 gas

Project:	TA-COMPACT-P vs TA-Modulator	IMI Hydronic Engineering
Date:	13.01.2016	
Made by:	Hydronic College	

Solution A: 34,640 kWh

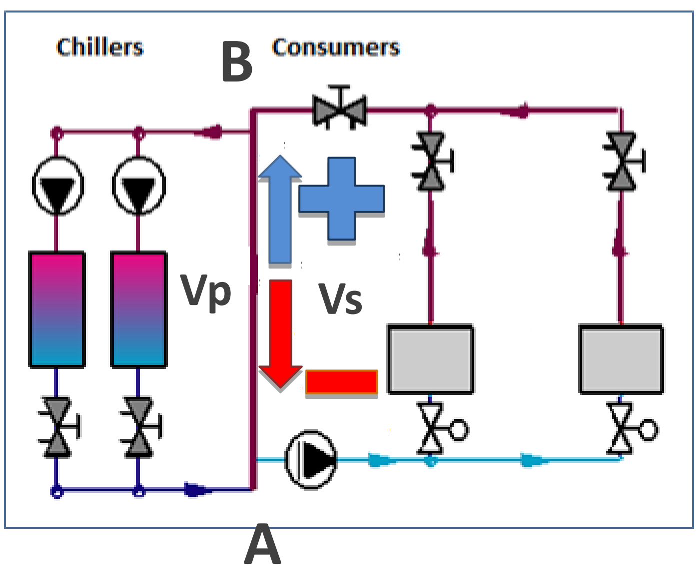
Solution B: 27,631 kWh

Savings:

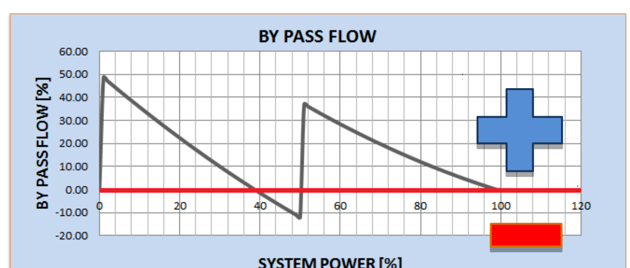
- **- 1,261 EUR**
- **- 1,051 kg CO_2**
- **- 20.2 %**

Chiller efficiency – Solution A

Result	
Real Seasonal Energy Effiecieny Ratio of the chiller	3.46
Average supply water temperature (Ts) of the chiller [°C]	6.5
Average return water temperature (Tr) of the chiller [°C]	8.6
Minimum controllable flow at the consumers [%]	2.0
Minimum controllable power at the consumers [%]	6.5
Thermal efficiency	0.29



By pass flow

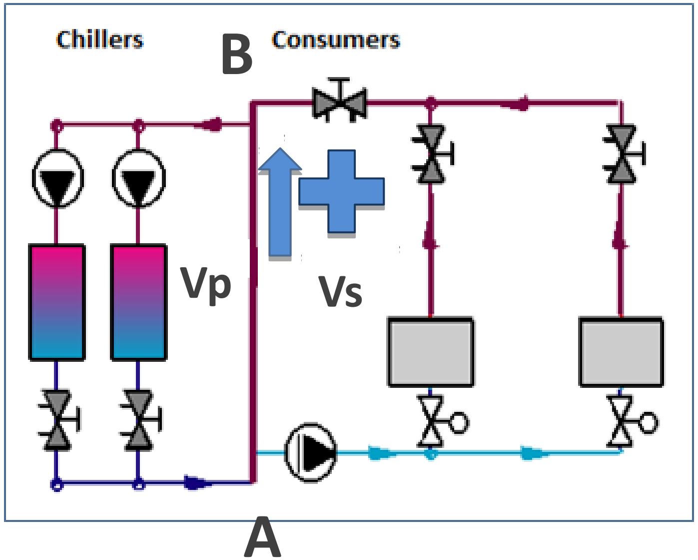


- **ON/OFF control (FC) & modulating control 1 (AHU)**
  - due to the **negative incompatibility** of the flows (Vs>Vp) the set point of the chiller is lower with 0.5 K (estimated value), see the graph!
  - due to the **ON/OFF control** the average **room temperarture of the building is lower** than the design value with: 0.5 K (estimated value)
  - **ESEER of the chiller:** 3.8 (optimum)

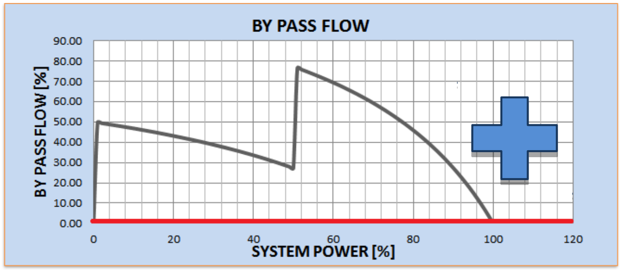
Chiller efficiency – Solution B

Result	
Real Seasonal Energy Effiecency Ratio of the chiller	3.60
Average supply water temperature (Ts) of the chiller [°C]	7.0
Average return water temperature (Tr) of the chiller [°C]	9.9
Minimum controllable flow at the consumers [%]	1.2
Minimum controllable power at the consumers [%]	4.0
Thermal efficiency	0.29

- **Modulating control (FC) & modulating control 2 (AHU)**
  - there is **no negative incompatibility** of flow
  - **accurate room temperature control**
  - **ESEER of the chiller:** 3.8 (optimum)



By pass flow



Chiller energy saving

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COMPARISON OF THE ANNUAL ENERGY COSTS

		Solution A			Solution B		
		Annual energy consumption**	Annual energy cost EUR/year	Annual CO_2 emission [kg/year]	Annual energy consumption**	Annual energy cost EUR/year	Annual CO_2 emission [kg/year]
Pump							
Fan coil		0.0	0.0	0.0	0.0	0.0	0.0
AHU		0.0	0.0	0.0	0.0	0.0	0.0
Chiller 1		0.0	0.0	0.0	0.0	0.0	0.0
Chiller 2		0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0
Chiller		529 079.4	95 234.3	79 361.9	475 055.0	85 509.9	71 258.3
Heat pump		0.0	0.0	0.0	0.0	0.0	0.0
Condensing boiler		0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	El. energy	529 079.4	95 234.3	79 361.9	475 055.0	85 509.9	71 258.3
	Gas	0.0	0.0	0.0	0.0	0.0	0.0
			95 234.3	79 361.9		85 509.9	71 258.3

Saving

-9 724.4	-8 103.7
Annual energy cost saving EUR/year	Annual CO2 emission saving [kg/year]

** [kWh/year] for the pumps, chillers and heat pumps

** [m3/year] for the condensing boilers

Price of electrical energy	0.18	EUR/kWh
Price of gas	0.00	EUR/m3
Specific CO_2 emission	150.0	g/kWh el. energy
Specific CO_2 emission	0.0	g/m3 gas

Project:	TA-COMPACT-P vs TA-Modulator	IMI Hydronic Engineering
Date:	13.01.2016	
Made by:	Hydronic College	

Solution A: 95,234 kWh

Solution B: 85,509 kWh

Savings:

- **- 9,724 EUR**
- **- 8,103 kg CO_2**
- **- 10.2 %**

Total energy saving

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COMPARISON OF THE ANNUAL ENERGY COSTS

Hydronic College

	Solution A			Solution B		
	Annual energy consumption**	Annual energy cost EUR/year	Annual CO_2 emission [kg/year]	Annual energy consumption**	Annual energy cost EUR/year	Annual CO_2 emission [kg/year]
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AHU	5 960.0	1 072.8	894.0	5 831.0	1 049.6	874.7
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Chiller 2	7 401.0	1 332.2	1 110.2	7 401.0	1 332.2	1 110.2
	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
Chiller	529 079.4	95 234.3	79 361.9	475 055.0	85 509.9	71 258.3
Heat pump	0.0	0.0	0.0	0.0	0.0	0.0
Condensing boiler	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL – El. energy	563 719.4	101 469.5	84 557.9	502 686.0	90 483.5	75 402.9
TOTAL – Gas	0.0	0.0	0.0	0.0	0.0	0.0
		101 469.5	84 557.9		90 483.5	75 402.9

Saving

Annual energy cost saving EUR/year	Annual CO2 emission saving [kg/year]
-10 986.0	-9 155.0

** [kWh/year] for the pumps, chillers and heat pumps

** [m3/year] for the condensing boilers

Price of electrical energy	**0.18**	EUR/kWh
Price of gas	**0.00**	EUR/m3
Specific CO_2 emission	**150.0**	g/kWh el. energy
Specific CO_2 emission	**0.0**	g/m3 gas

Project:	TA-COMPACT-P vs TA-Modulator	IMI Hydronic Engineering
Date:	13.01.2016	
Made by:	Hydronic College	

Solution A: 101,469 kWh

Solution B: 90,483 kWh

Savings:

- **- 10,986 EUR**
- **- 9,155 kg CO_2**
- **- 10.8 %**

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Thank you for your attention!

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