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Weather forecast control –

In comparison with some other control strategies

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Pictures: *Bondepraktikan*, 2010

Purpose and background

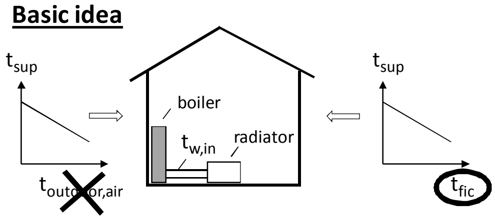
Does weather forecast control (WFC) save energy? If so… why and how much?

WFC as a concept was invented and introduced by SMHI (Swedish Meteorological and Hydrological Institute) in the 90th.

Today the concept is installed in >> 10 milj m^2 (almost only multi family buildings)

WFC providers claim it normally saves: 10 – 15 % or 10 – 20 kWh/m^2

Basic idea



t_{fic}= fictitious ”outdoor temperature”:

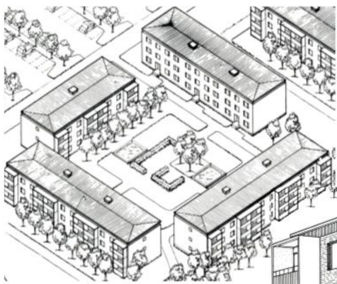
- wind speed
- outdoor air temperature ← *forecast*
- solar radiation
- internal heat
- building construction and geometry

Analysed control strategies

Strategy categories	Case	Description
”Traditional”	Case 1A	Without thermostats
	Case 1B	”Normal” thermostats
	Case 1C	Thermostats with perfect function
”Feed-back”	Case 2A	P-regulated feed-back control
	Case 2B	PI-regulated feed-back control
”Demand control”	Case 3A	Demand control supply
	Case 3B	Forecast demand control supply
”Perfect”	Case 4	Perfect control (theoretical)

Reference building (some data)

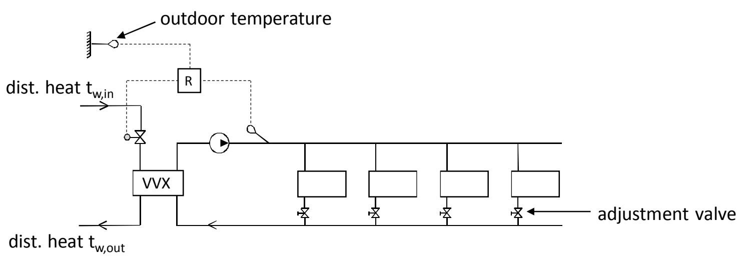
- Three-storey building from 1970-1975, Stockholm
- Apartments 18
- A_{floor} 1620 m^2
- Construction concrete
- Facade U: 0,41 $W/(m^2K)$
- Window U: 2,2 $W/(m^2K)$
- Roof U: 0,22 $W/(m^2K)$
- Air leakage 0,8 $l/(s{\cdot}m^2)$ at + 50 Pa
- Exhaust air 0,39 $l/(s{\cdot}m^2)$
- District heating
- People 2,2/apartment
- Lighting max 150 W/apartment (min 26 %)
- Equipment max 430 W/apartment (min 47 %)
- Domestic hot water 32 kWh/m^2



Picture: *Så byggdes husen 1880-200*

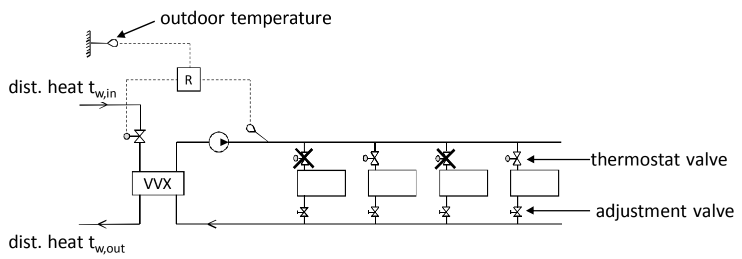
Traditional control strategy – Case 1A

Without thermostats



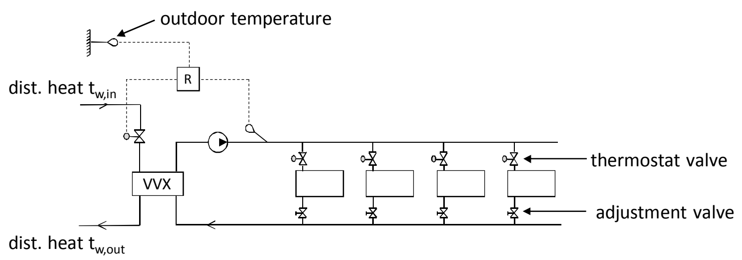
Traditional control strategy – Case 1B

With thermostats (”normal” function)



Traditional control strategy – Case 1C

With thermostats (perfect function)



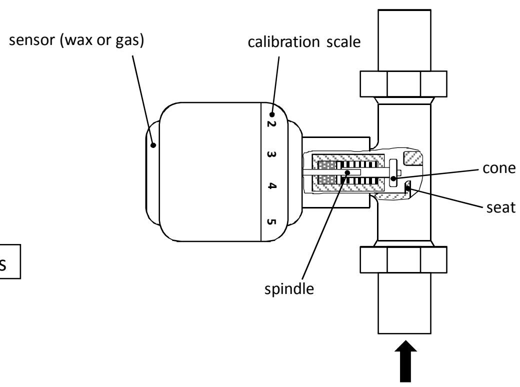
Why not just have good local control?

Because thermstat valves don’t have endless life…

Common problems
Valve spindle sticks
Increased hysteresis
Regulating range offset

Source: Byggforskningsrådet, 1989
and Svensk Fjärrvärme, 2003

Approximate lifetime: 10 years



Feed-back control strategy – Case 2

Adjustment of $t_{w,in}$ based on indoor temperature

The bigger difference between t_{set} and t_{room} the more ”work” for the feed-back

Questions when placing temperature sensors in building:

- Which apartment is representative?
- Where in the apartment is the room temperature representative?
- Damage?

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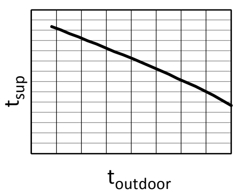
Selected placement: central exhauste air (exhauste kitchen air is not considered)

Case 2A: P-regulated feed-back

Case 2B: PI-regulated feed-back

Supply temperature

Case 1 – ”Traditional”



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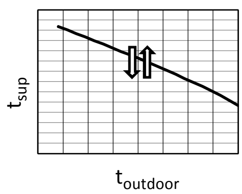
$t_{\text{sup}}(t_{outdoor})$

Case 2 – ”Feed-back”



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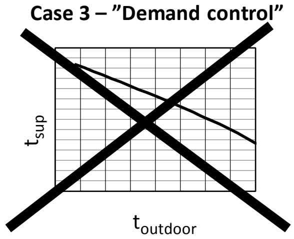
$t_{\text{sup}}(t_{outdoor}, t_{indoor})$

Case 3 – ”Demand control”



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$t_{\text{sup}}(\dot{Q}_{sol}, \dot{Q}_{\text{int}}, t_{outdoor}, wind, mass, thermostats, etc.)$

⇩

$t_{\text{sup}}(heatbalance)$

Demand control supply temperature – Case 3

Supply temperature equation – originally for adjustment of heating systems, based on temperature measurements (from Finnish doc thesis – Aalto 2010)

$$t_{sup} = t_{room,set} + \frac{e^{f^{(1-\frac{1}{n})} \cdot \frac{\Delta t_{w\,r}}{\Delta t_{\ln r}}} \cdot f \cdot \Delta t_{w\,r}}{e^{f^{(1-\frac{1}{n})} \cdot \frac{\Delta t_{w\,r}}{\Delta t_{\ln r}}} - 1}$$

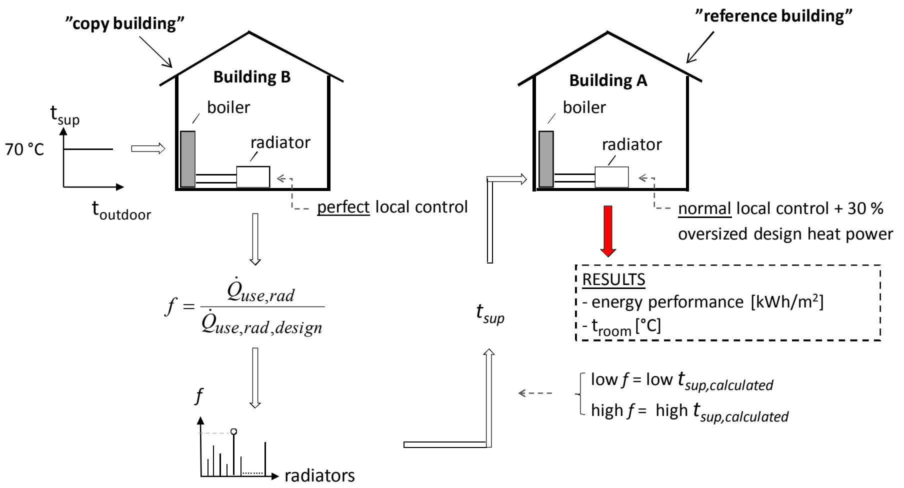
$t_{room,set}$:	indoor temperatur, set value	[°C]
f:	relativ heat power demand	[-]
n:	radiator exponent	[-]
$\Delta t_{w\,r}$:	water temperature drop at reference time	[°C]
$\Delta t_{ln\,r}$:	logaritmic mean temperature difference between room and radiator	[°C]

f = relative heat power: actual heat power demand in relation to a heat power demand at reference time (not necessary = design state)

$$f = \frac{\dot{Q}_{demand}}{\dot{Q}_{demand,r}}$$

$\dot{Q}_{demand}$	: actual heat power demand	[W]
$\dot{Q}_{demand,r}$	: heat power demand at reference time	[W]

Demand control through”copy building”

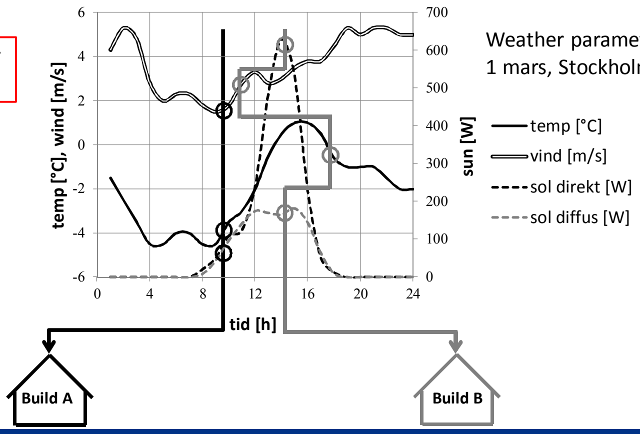


Time shifted weather (forecast)

Case 3B Demand controlled supply temperature with time shifted weather data

Perfect weather forecasts!

Weather parameters,
1 mars, Stockholm



Results – energy performance (heating)

Strategy	Case	Description	[kWh/m²]
”Traditional”	Case 1A	Without thermostats	165
	Case 1B	”Normal” thermostats	**148**
	Case 1C	Thermostats with perfect function	137
”Feed-back”	Case 2A	P-regulated feed-back control	141
	Case 2B	PI-regulated feed-back control	136
”Demand control”	Case 3A	Demand control supply	140
	Case 3B	Forecast demand control supply	138
”Perfect”	Case 4	Perfect control (theoretical)	126

Some conclusions so far

Weather forecast as a concept saves energy, but not mainly because of the forecasts
The energy savings comes from the fact that several parameters are considered (heat balance)

Time shifts of weather parameters increase the risk of having to low indoor temperature

Feed-back control can be a good alternative
But placing of temperature sensors can be tricky in practice and lead to poor thermal comfort

Working thermostat valves are important and efficient
Energy use can be reduced approx. 10 kWh/m^2 if ”normal functioning thermostats” are shifted to new ones (pay-off 3 years)

Role of thumb for lowered indoor temperature:
Energy use reduces 7 – 8 %/° C (not 5 % as ”guidelines” says)