Ventilation and Energy
– maybe not that irreconcilable

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Air change is one of the four natural components of the thermal balance of buildings, along with transmission through the envelope, internal gains and solar gains. These can be, and in most E.U. buildings in fact are, complemented by the artificial components of mechanical heating and/or cooling. However, the amount of heating and/or cooling that each room requires to be kept at a comfortable temperature depends on the results of the four natural components. This interaction will be here analyzed specifically in what regards the relation between air change and energy conservation, traditionally thought to be two conflicting interests.

The main mode of air change of rooms is Ventilation. It can occur naturally or be mechanically driven, but in either case it has the primary goal of removing "polluted" air from indoors and replace it with clean(er) outdoor air. The air flow of ventilation that is needed for each room is usually determined, directly or indirectly, by indoor air quality requirements. It does however have an important impact on the energy balance of buildings. This impact can, in some moments of the year, be favorable the energy economy. E.g., increasing the air flow in mid-season or summer in cold or mild climates can contribute to decrease the energy demand for cooling (night cooling and free-cooling). However it is clear that for most buildings and European climates the effect of air change that dominates is the increase of the energy demand for heating.

In fact, the notion that ventilation has a negative impact on the objectives of energy conservation has long set foot on the policy-making fields. It is a matter of historical record that there was sometimes a trend for ventilation rates to decrease when the price of oil had increased. Not even the progresses of the latest years, when new technologies such as mechanical ventilation with heat recovery or demand-control ventilation, have appeared, or been perfected, or become affordable, have removed this perception. And, in fact, it should not be taken for granted without a thorough analysis that they do fully solve the problem in every climatic context. For instance, mechanical ventilation with heat recovery or free-cooling saves thermal energy but requires additional electricity to drive the fans, therefore producing a trade-off that must be analyzed in the diversity of contexts before general conclusions are drawn.

An opportunity for such a thorough analysis considering the wide diversity of climates, building types, building characteristics and ventilation systems was recently

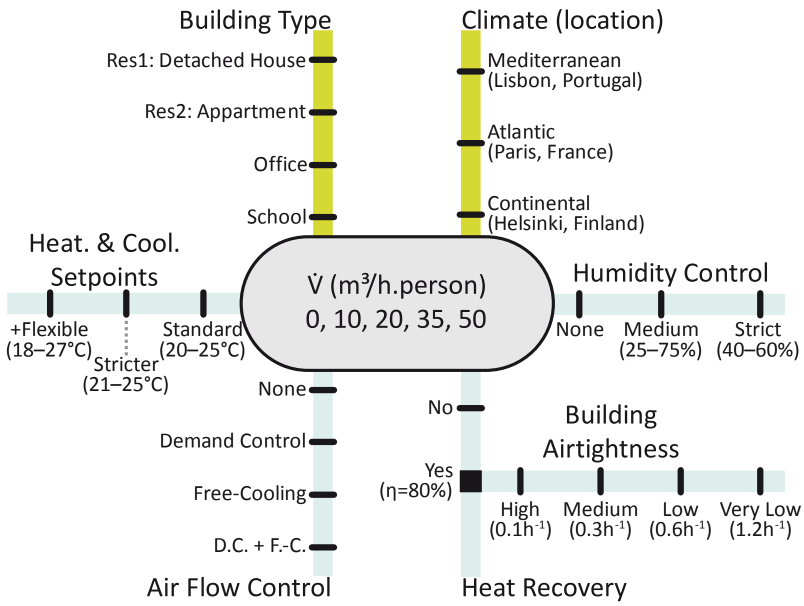

Figure 1. Schematic view of variables addressed in the study.

created in the frame of the Healthvent project (www.healthvent.eu). This project has the quite ambitious goal of developing a rationale to identify the recommendable ventilation practices for the most important building types (or room types) from a purely health-based criteria. Energy does not play there an important decision role, but it is intended that the impact of the health-based recommendations – yet to be finalized – be assessed in several dimensions, including impact on energy demand and GHG emissions.

The framework created for this analysis of the energy impact of ventilation rates is represented in **Figure 1.** It tries to capture the diversity of climates, building types, building characteristics and ventilation systems existing in Europe. A main decision was that the "impact of ventilation rates" would be assessed through the slope of the graphical representation of the results of the calculated energy demand versus the ventilation rate, thus resulting in the units of [(kWh/m².a)/(m³/h.person)]. This impact was assessed at two levels: first at the level of thermal energy needs for heating and cooling, and second in terms of overall energy for heating, cooling and moving the air. The results later confirmed that this relation is nearly linear in almost every case analyzed, thus validating the approach. In order to find the slope, each case-study was run at five different ventilation rates, ranging from 0 to 50 m³/h.person.

Besides the ventilation rate, the other variables identified as being of problem-shaping nature were the building type (four considered: a detached dwelling, an apartment, an office and a school), the climate (three considered: Lisbon, Paris and Helsinki), the heating and cooling set points (standard 20–25°C, stricter 21–25°C or flexible 18–27°C), the type of air flow control (no control/constant ventilation, demand control, free-cooling, combined demand control and free-cooling), humidity control (none, medium allowing a band between 25% and 75% RH, and strict imposing a band between 40% and 60%) and the existence of heat recovery. This later requires balanced or nearly balanced ventilation to operate at maximum efficiency, and therefore prompts the issue of the airtightness of the building envelope (the cases of 0.1, 0.3, 0.6 or 1.2 ach^{-1} on average were considered).

The variables were organized and discretized according to **Figure 1**. For each building and climate a base-case combination of the characteristics was defined. The characteristics of building envelope and operation were adapted to each climate, according to information supplied by local experts, and are summarized in **Table 1**.

A sensitivity analysis was performed to one variable at a time, starting from the base-case. In the end, an "advanced system" combining advanced features in each of the variables was also considered. This "advanced system" is characterized by a very airtight envelope, high efficiency heat recovery, demand control and free-cooling. **Table 2** shows the characteristics of the base-case for each building and climate, as well as the characteristics of the advanced system considered.

The results were first assessed in needs of thermal energy for heating and cooling. This assessment was performed through dynamic simulation with the software ESP-r. **Figure 2** shows these results for the detached dwelling for the base-case and for the advanced system in each of the three reference climates considered. The results show very clearly that the slope of the variation "thermal energy vs. air flow" becomes much lower with an advanced system than with the base-case/current practice systems in most building-climate combinations. In many cases with the advanced system this slope even becomes nearly zero, revealing an almost negligible influence of the minimum ventilation air flow rate in the thermal energy demand.

In order to integrate into the analysis the energy needed to drive the fans, as well as to consider the fact that ▶

Table 1. Main characteristics of the four building models analyzed.

			Dwelling	Apartment	Office	School
Useful Area (m²)			150	72	298	464
Regular Occupants			4	3	32	136 children + 10 adults
Designed Occupation			8	6	35	152
Vent. hours/day & days/week (without demand. control)			24/7	24/7	13/5	11/5
Typical Infiltration Rate (ach^{-1})		Lisbon	0.6	0.6	0.6	0.6
		Paris	0.3	0.3	0.3	0.3
		Helsinki	0.1	0.1	0.1	0.1
U-Values [W/(m²·°C)]	Exterior Wall	Lisbon	0.46	0.57	0.57	0.57
		Paris	0.16	0.16	0.16	0.16
		Helsinki	0.16	0.16	0.16	0.16
	Interior Wall 1	Lisbon	1.77	1.7	0.9	0.9
		Paris	0.25	0.27	0.43	0.43
		Helsinki	1.77	1.4	0.26	0.26
	Interior Wall 2	Lisbon	0.47	1.2		
		Paris	0.17	0.43	n.a.	n.a.
		Helsinki	0.18	0.45		
	Floor Slab	Lisbon	1.72	1.77	1.2	1.4
		Paris	0.37	0.39	0.39	0.39
		Helsinki	1.72	1.77	1.2	1.2
	Roof Slab	Lisbon	0.41			0.4
		Paris	0.29	n.a.	n.a.	0.1
		Helsinki	0.09			0.09
	Ground Slab	Lisbon	0.67			0.67
		Paris	0.22	n.a.	n.a.	0.19
		Helsinki	0.17			0.16
	Windows	Lisbon	2.7	2.7	2.7	2.7
		Paris	1.5	1.5	1.5	1.5
		Helsinki	1.0	1.0	1.0	1.0

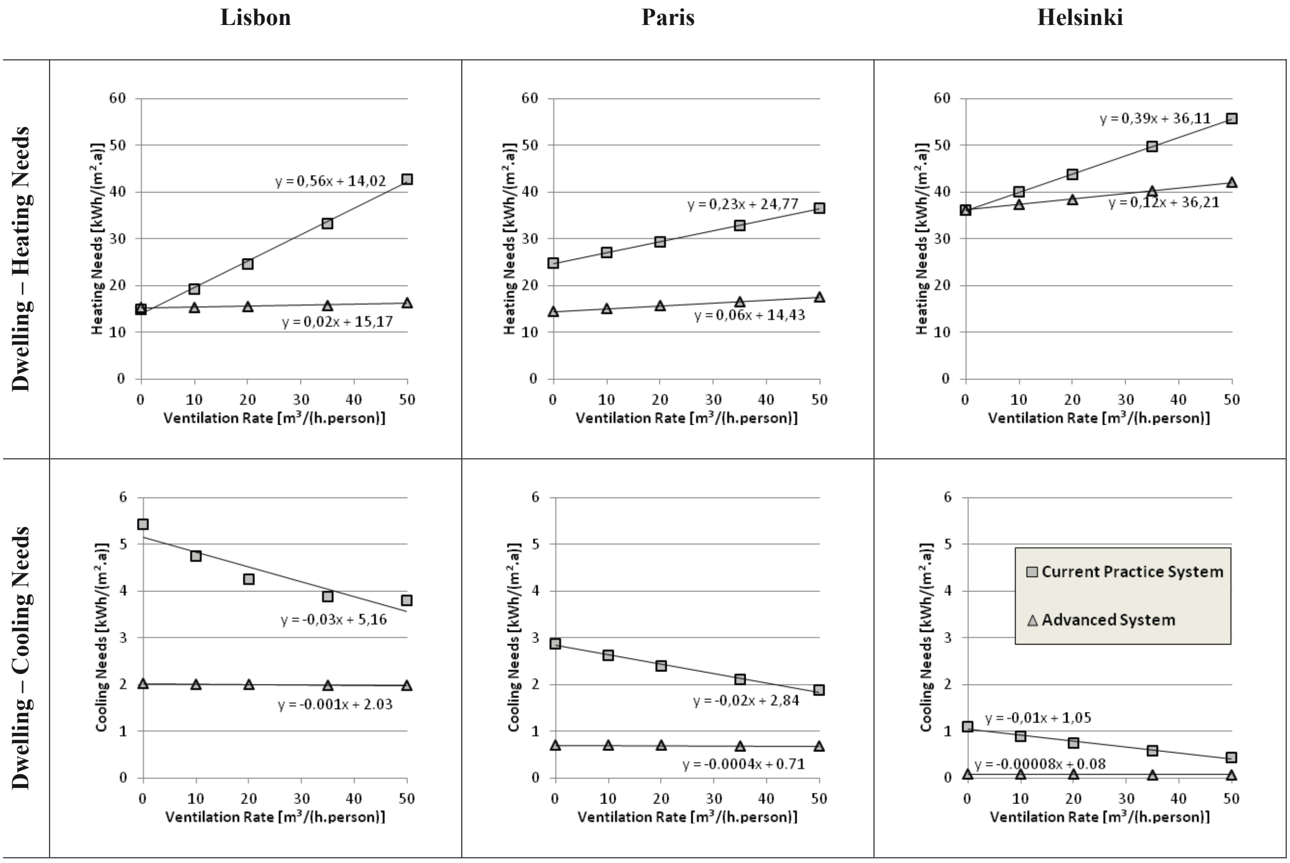

Figure 2. Heating and cooling needs versus ventilation rate with typical and advanced systems in the dwelling model and in three locations.

Table 2. Characteristics of the current practice system and of the advanced systems considered.

		Dwelling		Apartment		Office		School	
		Curr. pract.	Adv. sys.	Curr. pract.	Adv. sys.	Curr. pract.	Adv. sys.	Curr. pract.	Adv. sys.
Lisbon	Av. Infiltration Rate (ach^{-1})	0 *	0.1	0 *	0.1	0.6	0.1	0.6	0.1
	Ventilation Control	None	DCFC	None	DCFC	None	DCFC	None	DCFC
	Heat Recovery	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Paris	Av. Infiltration Rate (ach^{-1})	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1
	Ventilation Control	None	DCFC	None	DCFC	None	DCFC	None	DCFC
	Heat Recovery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Helsinki	Av. Infiltration Rate (ach^{-1})	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Ventilation Control	None	DCFC	None	DCFC	None	DCFC	None	DCFC
	Heat Recovery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* the building is considered to be over-pressured, hence eliminating infiltrations.

DCFC: Demand-control and free-cooling.

heating and cooling are usually provided with different efficiencies, an analysis was also made in terms of delivered energy. For this purpose the reference conversion scheme considered that heating is provided by a heat pump-base system (either air or ground-source), that cooling is provided by a refrigerating machine and that in the cases of mechanical ventilation air is moved through a duct and fan system with an average specific fan power. It must however be stressed that the adoption of this reference system was made only for convenience for integrating the several components of the HVAC energy demand into a single indicator – it therefore does not necessarily represent a recommendation in itself.

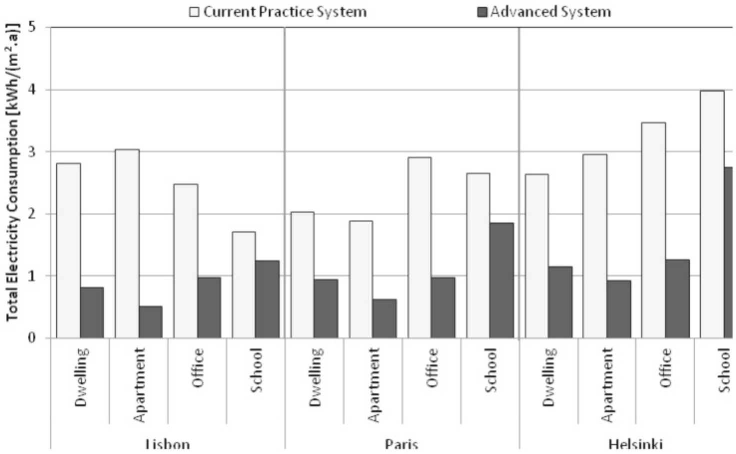

Figure 3. Impact upon total HVAC-related delivered energy of changing ventilation by 10 m^3/(h.person), in a scenario with a current practice system and in a scenario with an advanced system, for different locations and case-study buildings.

Figure 3 shows the impact of changing the air flow rate by 10 m^3/(h.person) in the total electricity consumption for heating, cooling and moving the air, with the current practice system and with the advanced system. As had happened for the thermal energy alone, the results show that the impacts of the variations are much smaller with the advanced system than with the current practice system. In the case of the advanced systems, the impact of changing the ventilation rate by 10 m^3/(h.person) is never more than 2 kWh/(m^2.year) in delivered energy.

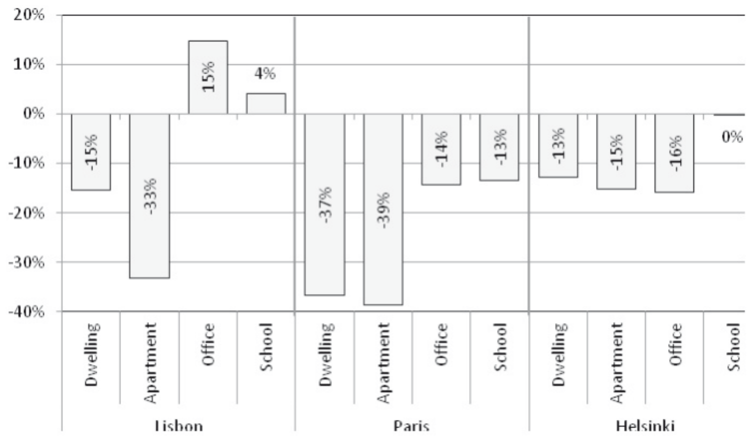

Figure 4. Percent change in HVAC-related delivered energy demand if hypothetically but simulataneously increasing the ventilation rate from 20 to 30 m^3/h.person and adopting advanced ventilation systems with airtght building envelopes, heat recovery, demand control and free-cooling.

Figure 4 expresses the previous results in the form of percent change implied by a hypothetical increase of the ventilation rates from 20 m^2/(h.person) with a current practice system to 30 m^3/(h.person) with an advanced system. It shows that, in all but two cases, should there be a need to increase ventilation rates – something that is far from being established but which is not the topic of discussion here – the energy impact of this measure could be effectively mitigated by adopting more advanced ventilation systems and airtight envelopes.

While these results confirm that the impact of increasing or decreasing ventilation rates in a "per person" base can be effectively mitigated, at least two other important questions arise that require further study. One is the issue of the cost-effectiveness of adopting advanced systems "everywhere" in Europe. The other, not less important, is whether very airtight buildings are compatible with the local culture of many European regions, where the building is often perceived, at least for a significant part of the year, more as an extension from the outdoor environment than as a shelter from it.