INNOVATIONS IN VENTILATION TECHNOLOGY

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AIRFLOW RATE IN THE DWELLINGS

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SYNOPSIS

In France, the regulation on residential building ventilation is based, since 1969, on a general and continuous air renewal ; the fresh air comes into habitable rooms by air inlets and the stale air is drawn out to exhaust vents in the service rooms. So the air inters the habitable rooms crosses through the dwelling, is extracted in the service rooms.

The Research and Development Division of Gaz de France and the CSTB have studied the needs in each room of a dwelling (depending on the size and the occupancy) to perform new ventilation system(s). The study has been conducted in accordance with the methodology developed in the IEA annex 27 using the CSTB computer code SIREN95.

This paper presents the main results of the study:

- It's necessary to provide punctual high flow rate level in service rooms, in order to evacuate quickly humidity, especially during clothes drying, shower taking and cooking,
- The extract flows needs in the service rooms are not necessary adapted to the fresh air needs in the habitable rooms,
- It is necessary to provide a minimum flow rate to extract pollutants due to the dwelling itself (materials, furnitures, …),

and describes the principle of a new ventilation system allowing both indoor air quality and energy saving.

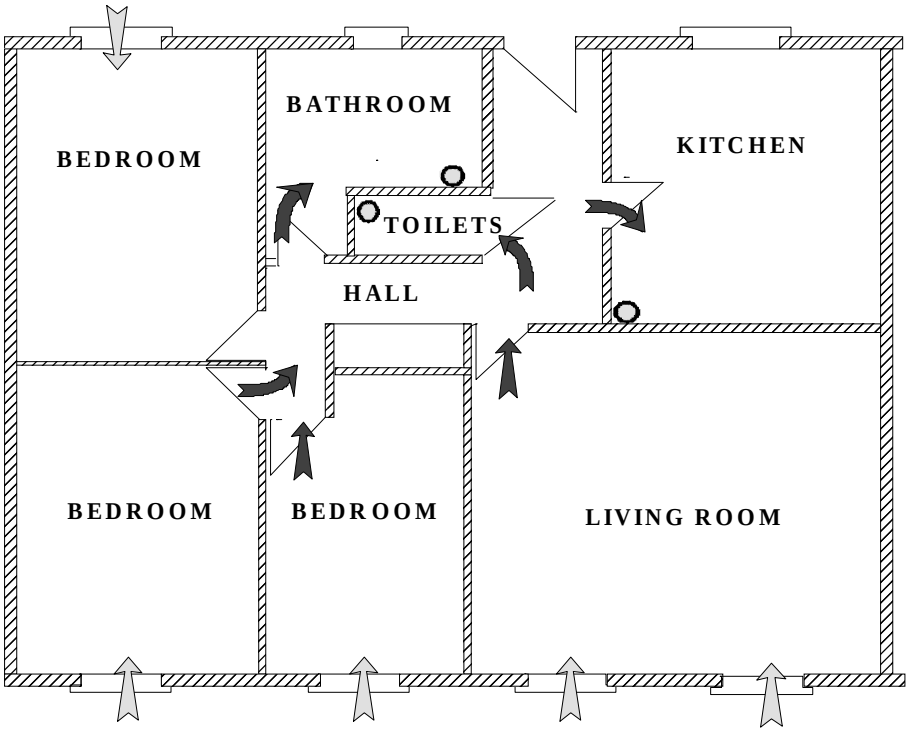
1. FRENCH VENTILATION

In France, since 1969, the ventilation system for dwelling is required to continuously exhaust stale air from the service rooms. [1]

The extract airflow rate depends on the number of habitable rooms ; additionally, a higher flow rate level for kitchens is proposed, depending on the size of the dwelling.

	number of habitable rooms						
	1	2	3	4	5	6	7
normal flow (m^3/h)	35	60	75	90	105	120	135
high level flow (m^3/h)	90	120	150	180	210	210	210

The fresh air incomes in the habitable rooms by inlets generally located in the window frame. So the air incomes in the habitable rooms, passes through the dwelling, is extracted in the service rooms.



airflows in a dwelling

inlets are located in living room and bedrooms,
exhaust vents are located in kitchen, bathroom and toilets.

The mechanical exhaust systems are now the most commonly used. The passive stack ventilation systems were used in the seventies but are now only used in one family houses. Balanced systems represent a few part (1%) of the market.

2. OBJECTIVE OF THE STUDY

The objective of the study is to infer, from requirement in terms of indoor air quality, the airflows rate to be implemented in each room of a dwelling.

After specifying the essential criterions to be taken into account, we calculate, room by room, the airflows rate to comply with these criterions. The study of these airflows rate and their influence on the assessment index define by the IEA annex 27 allows to appreciate the relevance of the criterion carried out :

- CO2 for habitable rooms
- humidity for habitable rooms and service rooms
- cooking products for the kitchen

3. METHODOLOGY

The methodology to assess the ventilation systems, at the same time in indoor air quality, condensation risk and energy losses due to air renewal, has been developed in the IEA annex27 works [2&3]. Calculation are conducted with the computer code SIREN95 [4]

Indoor air quality is estimated by occupant exposure to generic pollutants :

- Plt1 : this pollutant is based on a constant emission related to the room area. It could be related to pollutant emission by the rooms themselves.
- Plt2 : this pollutant is related to human metabolism. It is based on CO2 production.
- Plt3 : this pollutant is related to cooking activities. It is proportional to the water evaporated during cooking and could be related to odours production, as to CO and NOx production in case of gas appliance.
- Plt4 : this pollutant is related to passive smoking. It is based on a constant production of pollutant for the hours and place when and where people are smoking.
- Indoor humidity : this one is only related to the dryness feeling. It is not a generic pollutant as it can be expressed directly in term of indoor relative humidity

Condensation risks are calculated in hours of possible condensation on :

- a single glazing window (U = 6 W/m^2.K)
- a double glazing window (U = 3 W/m^2.K)
- an internal wall (U = 0 W/m^2.K)

4. CASE STUDY

4.1 DWELLINGS

The dwellings are described in the typology of the French dwellings [5]. Two types of dwellings are selected for this study :

- a studio flat : (so called "Picasso"),
- a four habitable rooms single family house built at street level (so called "Mozart").

4.2 CLIMATES

Three French climates :

- cold : Nancy (east of France) : heating season 243 days, 2950 degree days base 18 °C
- mild : Trappes (near Paris) : heating season 241 days, 2760 degree days base 18 °C
- warm : Nice (south of France) : heating season 161 days, 1300 degree days base 18 °C

4.3 OCCUPANCY

Occupancies are specified in accordance with IEA Annex 27 occupancy schedule :

Three occupancies for the single family house :

- spacious : two persons,
- average : four persons (two adults and two children)
- crowded : five persons (two adults and three children)

One occupancy for the studio flat : one person.

4.4 POLLUTANT PRODUCTION

Metabolic production

	adult		children	
	sleeping	awake	sleeping	awake
H2O production (g/h)	30	55	15	45
CO2 production (l/h)	12	18	8	12

Other water vapour production

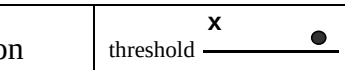
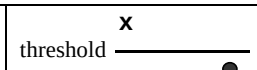
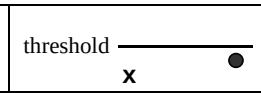
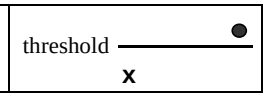
Kitchen		week day		week-end	
		production (g)	hours	production (g)	hours
MOZART 2 persons	breakfast	100	7:00-7:30	100	9:00-10:00
	lunch	0	/	300	11:00-12:00
	dinner	600	17:00-18:00	600	17:00-18:00
MOZART 4 persons	breakfast	200	7:00-8:00	150 50	9:00-10:00 10:00-10:30
	lunch	150	12:00-13:00	0	/
	dinner	1200	17:00-18:00	1200	17:00-18:00
MOZART 5 persons	breakfast	100 150	7:00-7:30 7:30-8:00	100 100	9:00-10:00 10:00-11:00
	lunch	0	/	750	11:00-12:00
	dinner	1500	17:00-18:00	1500	17:00-18:00
PICASSO 1 person	breakfast	50	7:00-7:30	50	7:00-7:30
	lunch	150	12:00-13:00	150	11:00-12:00
	dinner	300	17:00-18:00	300	17:00-18:00

Shower		week days		week-end	
		production	hours	production	hours
MOZART 2 persons	woman	300	6:30-7:00	300	9:30:10:00
	man	300	6:00-6:30	300	9:00-9:30
MOZART 4 persons	woman	300	6:30-7:00	300	9:30-10:00
	man	300	6:00-6:30	300	9:30-10:00
	child 1	300	7:00-7:30	300	10:00-10:30
	child 2	300	7:30-8:00	300	9:00-9:30
MOZART 5 persons	woman	300	6:30-7:00	300	9:30-10:00
	man	300	6:00-6:30	300	9:00-9:30
	child 1	300	7:00-7:30	/	/
	child 2	300	7:00-7:30	300	11:00-11:30
	child 3	300	7:30-8:00	300	10:00-10:30
PICASSO		300	7:00-7:30	/	/

4.5 AIRFLOWS CALCULATION

Airflows rate values are calculated at each time step (3 minutes) :

- the pollutant concentrations are calculated,
- the airflow rate is adjusted by steps of 0,5 m^3/h as the pollutant concentration is less than the chosen value following the next diagram (the cross is the value before incrementation, the circle the value after incrementation) :

concentration				
incrementation	+0,5 m^3/h	end of calculation	-0,5 m^3/h	+0,5 m^3/h

the minimal airflow rate is 1 m^3/h ; there is no limit for the maximum airflow rate.

5. RESULTS

5.1 CONDENSED RESULTS FOR A WHOLE HEATING SEASON

Reference system : the reference ventilation system is a mechanical extract only system with airflow rate in accordance with French regulation (see table in § 1).
In the habitable room we give for each parameter taken into account, the pollutant exposure (hours) of the most exposed occupant . Condensations (hours) in habitable rooms and service rooms are calculated for a double glasses window.

Habitable rooms	**Studio flat**			**Single family house**								
	1 person			2 persons			4 persons			5 persons		
	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.
CO2 700 ppm	136	135	90	935	952	461	1376	1401	739	1826	1721	1687
CO2 1400 ppm	0	0	0	64	81	4	77	102	13	179	145	126
U1 (materials)	1516	1501	1003	2958	2969	1839	2735	2762	2011	2660	2689	1992
U4 (passive smoking)				309	308	202	568	568	374	568	568	374
dryness feeling	468	251	94	235	95	47	501	206	119	34	11	23
condensations	70	73	40	0	0	0	0	0	0	0	0	0

Kitchen	**Studio flat**			**Single family house**								
	1 person			2 persons			4 persons			5 persons		
	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.
U3 (effluents cuisine)	413	410	374	462	455	305	963	954	634	1126	1118	746
condensations	8 39	9 41	7 30	134 212	144 226	92 146	403 699	414 726	275 490	461 902	478 929	313 619

CO2 concentration limited to 700 ppm (above outdoor)

Habitable rooms	Studio flat			Single family house								
	1 person			2 persons			4 persons			5 persons		
	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.
CO2 700 ppm	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
CO2 1400 ppm	0	0	0	0	0	0	0	0	0	0	0	0
U1 (materials)	4241	4206	2810	8062	8000	5346	6973	6914	4616	4420	4387	2933
U4 (passive smoking)				411	408	273	459	456	305	413	410	275
dryness feeling	5094	5009	3380	4369	4317	2892	4228	4194	2802	4121	4091	2736
condensations	0	0	0	6	0	0	0	0	0	0	0	0

The occupants exposure to 700 ppm CO2 concentration is of course zero (all the more so 1400 ppm).

There are no condensation risks. On the other hand the dryness feeling is very important (in a ratio of 100 to 1 in comparison with the reference system).

The occupants exposure to pollutant U1 is important (in a ratio of 3 to 1 in comparison with the reference system). It means that it is therefore **necessary to keep a minimum airflow rate even if no occupant.**

For a same dwelling the differences according to the number of occupant is linked, for one hand, to the attendance time, and for the other hand because more are the occupants, more quickly the airflow reaches this cruising value.

For passive smoking the exposure is slightly bigger than for the reference system.

CO2 concentration limited to 1400 ppm (above outdoor)

Habitable rooms	Studio flat			Single family house								
	1 person			2 persons			4 persons			5 persons		
	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.
CO2 700 ppm	2844	2821	1885	2253	2236	1495	2595	2576	1723	2623	2604	1742
CO2 1400 ppm	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
U1 (materials)	8493	8423	5627	13257	13158	8803	13542	13430	8971	8861	8794	5881
U4 (passive smoking)				792	787	528	827	821	549	754	749	502
dryness feeling	4377	4161	2521	3839	3699	2295	3817	3654	2292	3753	3582	2256
condensations	3	10	431	44	69	612	19	223	819	11	155	737

The occupant exposure to 1400 ppm CO2 concentration is of course zero. On the other hand the occupant exposure to 700 ppm of CO2 is in a ration of 20 to 1 for the studio flat, and in a ration of 2 or 3 to 1 for the single family house.

Condensation risks exist in Nice, and the dryness feeling remain important.

The occupant exposure to pollutant U1 is in a ratio of 2 to 1 in comparison with the precedent system . It is therefore necessary to keep a minimum airflow rate even if no occupant.

Condensation risks on a double glasses window (U = 3 W/m².°C)

Habitable rooms	Studio flat			Single family house								
	1 person			2 persons			4 persons			5 persons		
	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.
CO2 700 ppm	9299	9025	5427	6959	6695	4226	7989	7707	4979	7923	7604	4827
CO2 1400 ppm	6087	5858	3313	4391	4136	2494	5168	4913	3107	5103	4823	2983
U1 (materials)	21707	20957	12828	23693	23126	15240	24052	23335	15243	17845	17132	11079
U4 (passive smoking)				1967	1873	1097	1746	1627	998	1642	1523	953
dryness feeling	4	2	2	165	155	57	0	0	0	0	0	0
condensations	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

The condensation risks are of course zero

In the single-family house occupied by two persons the dryness feeling is near the values given by the reference system ; they are equal to zero for the other occupancies.

The exposure of all the other pollutants are very important and can be in a ratio of 10 to 1 in comparison with the reference system..

Kitchen : U3 limited at 5 (unit of U3)

Kitchen	Studio flat			Single family house								
	1 person			2 persons			4 persons			5 persons		
	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.
U3 (cooking products)	**2661**	**2639**	**1763**	**3120**	**3097**	**2072**	**3089**	**3063**	**2046**	**2599**	**2583**	**1730**
condensations	2474	2252	1454	3640	3389	1556	2654	2612	2234	2488	2664	2610

Kitchen : condensation risk on an internal wall (U = 0 W/m².°C)

Kitchen	Studio flat			Single family house								
	1 person			2 persons			4 persons			5 persons		
	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.	Na.	Tr.	Ni.
U3 (cooking products)	2210	2124	1339	2440	2341	1502	2642	2556	1647	2279	2202	1404
condensations	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

With this two system the exposure to pollutant U3 is important ; but the second system eliminate (of course) the condensation risks.

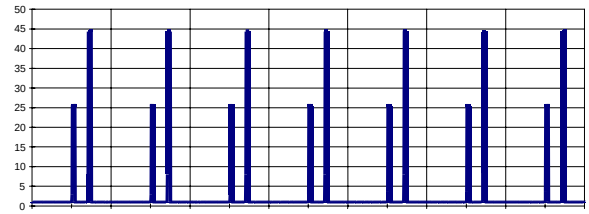
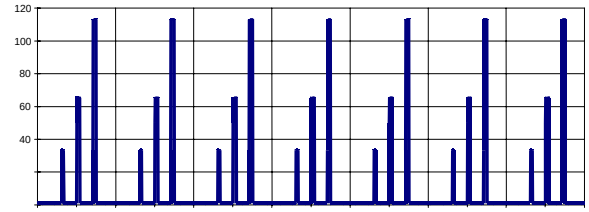
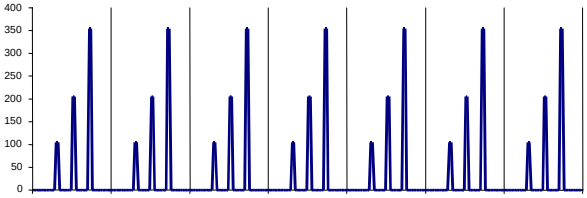
5.2 AIRFLOWS RATE EVOLUTION DURING ONE WEEK

The airflows rate in the habitable rooms and in the service rooms have been calculated during two weeks type, with constant outdoor temperature and humidity :

- 0 °C 80 % RH (3 g water vapour per kg air)
- 12 °C 80 % RH (7 g water vapour per kg air)

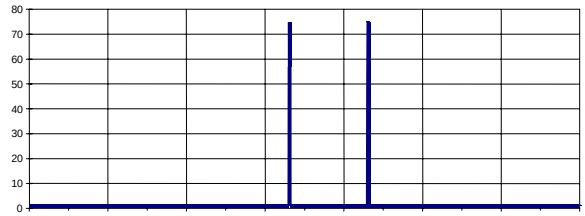
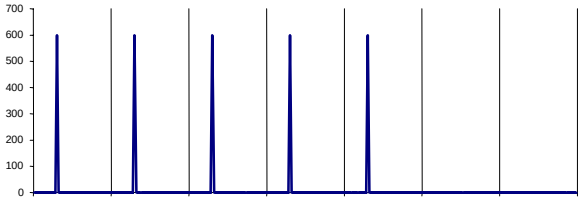
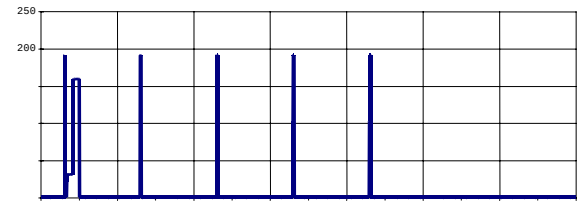
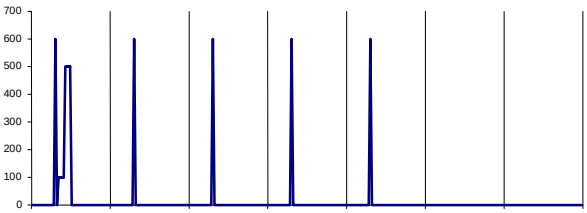
We give hereafter some results.

Studio flat, kitchen : no condensations on an internal wall

Airflows (m3/h) from Monday to Sunday	Water vapour production (g/h)
(Tout = 0 °C)  (Tout = 12 °C) 	

At breakfast times the H2O peak doesn't correspond to an airflow peak (if Tout = 0 °C) ; the kitchen volume is big enough to play the role of buffer.

Studio flat, bathroom : no condensations on an internal wall ; Tout = 0 °C

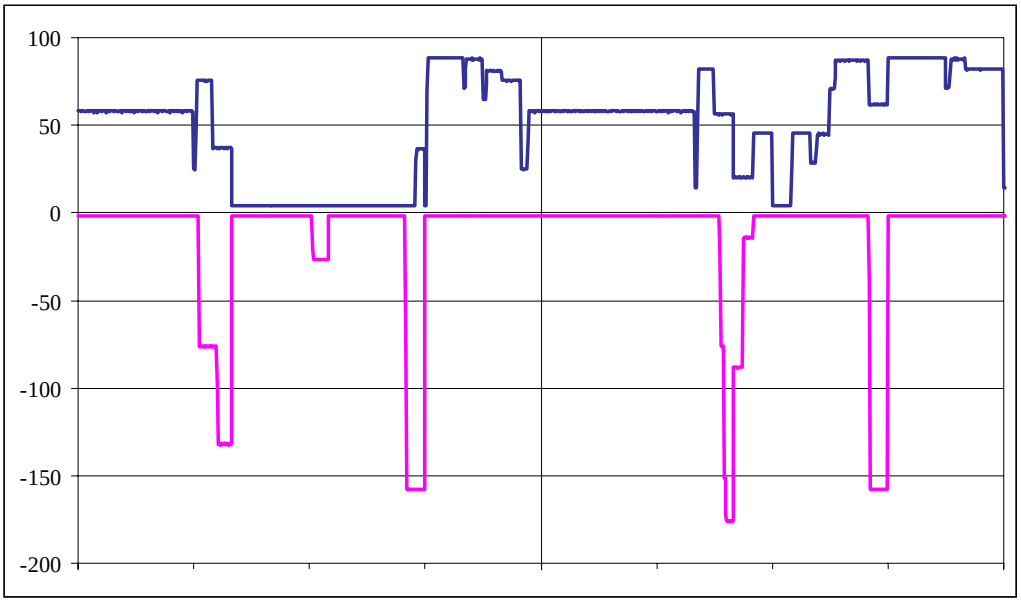
Airflows (m3/h) from Monday to Sunday	Water vapour production (g/h)
	shower only 
	shower + clothes washing + clothes drying 

Without washing, the three first days, the H2O peak doesn't correspond to an airflow peak ; the bathroom volume is big enough to play the role of buffer.

5.3 AIRFLOW NEEDS IN HABITABLE ROOMS AND SERVICE ROOMS

The chart hereafter, shows the airflows in habitable rooms (for a CO2 level of 1400 ppm) and in the service rooms (no condensation on an internal wall, outdoor temperature 0 °C).

The flows in habitable rooms are given positive values, and in negative values in the service rooms. The chart represents two days (Friday and Saturday)



This chart shows the not concomitance of the needs in habitable rooms and in service rooms : so ventilation systems using a sweeping of the dwelling are not necessary the most adapted.

6. THE PROPOUNDED VENTILATION SYSTEM

The mains results of this study are :

- It is necessary to keep a minimum airflow rate even if no occupant, to eliminate the pollutant emission by the rooms themselves,
- Peak airflows rate in service rooms are to be important to quickly eliminate the humidity produced,
- There is rarely concomitance between the needs in habitable rooms an the needs in service rooms,
- The energy losses due to ventilation are important.

The propounded ventilation system fit these points.

6.1 FIRST APPROACH

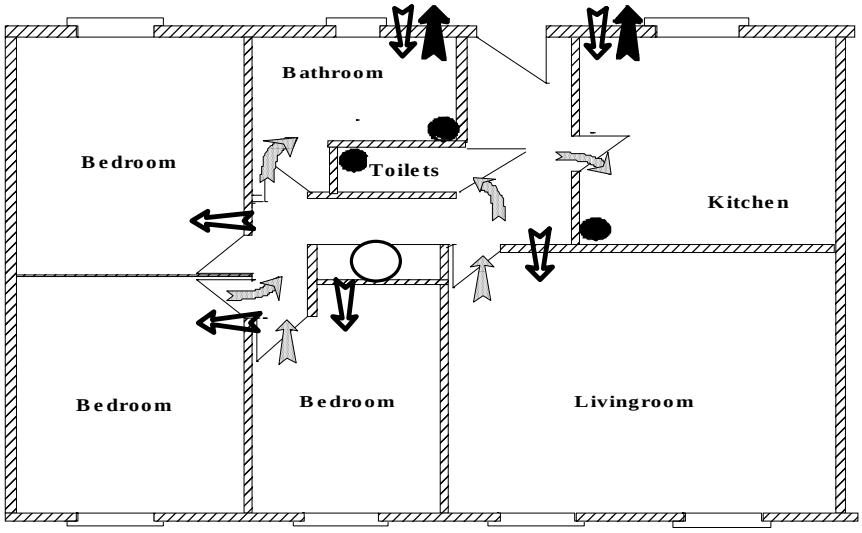
1) A continuous ventilation system sweeps the dwelling (fresh air introduced in habitable rooms, stale air extracted in service rooms) to extract pollutants due to the dwelling itself. This system can be a mechanical balanced system or an extract only system (inlets in habitable rooms, extraction mechanical or using natural forces in service rooms).
2) In each habitable room, a localised balanced system (with or without heat recovery). This system runs only if occupants are present in the room (infra-red detection, CO2 controlled, humidity controlled, …).
3) In each service room, a localised balanced system controlled by the occupant (with or without temporised command)

This system don't be finally accepted, because his complexity (possible problems for implementing and maintenance) and his foreseeable cost.

6.2 SYSTEM ACCEPTED

The ventilation system accepted is a simplification of the previous described.

1) A continuous ventilation system sweeps the dwelling (fresh air introduced in habitable rooms, stale air extracted in service rooms) to extract pollutants due to the dwelling itself **and to provide indoor air quality in habitable rooms**.
   This system can be a mechanical balanced system (with or without heat recovery) or an extract only system (inlets in habitable rooms, extraction mechanical or using natural forces in service rooms).
2) In bathroom and kitchen, a localised balanced system controlled by the occupant (with or without temporised command).



Continuous ventilation system **(here balanced)**

central fresh air

fresh air in habitable rooms

stale air in service rooms

Localized balanced ventilation system in service rooms

6.3 INDUSTRIAL OFFER

The technology of the continuous ventilation system is well known ; components and systems are present on French market just as well for mechanical systems (extract only or balanced), than for passive stack systems.

Kitchen hood using induction principle (air intake and outlet in the same component) are widely used in tertiary kitchen.
One French industrial has developed such a product for dwelling.

A specific product for bathroom doesn't exist on French market and has to be developed.

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