VENTILATION AND COOLING

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IEA ANNEX 27: Evaluation and Demonstration of Domestic Ventilation Systems. A simplified tool for the assessment of LCC

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SYNOPSIS

Costs are one of the main decision factors for the selection of domestic ventilation systems. This often leads to a ventilation system that just meets the requirements of building regulations at the lowest initial costs. Decision makers are often not aware of the impact of the quality of the ventilation system on life cycle costs, not only for the ventilation system itself but also for the building, as a result of complaints or even damage due to a poor functioning ventilation system. In Annex 27 a simplified tool is developed to compare costs of ventilation systems, not only regarding the initial costs of the system, but also costs of maintenance and costs of complaints and failures related to ventilation and ventilation systems. Little is known about these costs, specially costs of maintenance and complaints. To collect some data a survey was carried out amongst 19 housing corporations, owning about 100,000 homes, and representatives of the Dutch ventilation industry (VLA).
The first step was to put up a framework for the tool. With data and information of the Dutch ventilation industry and four housing corporations, owning buildings and homes with different types of ventilation systems (ME and MVHR), types of maintenance activities as well as maintenance cycles were defined. The second step was to estimate a relation between the user frequency, basic quality and the expected maintenance level, depending on the type of ventilation system. As a prerequisite it was assumed that a certain maintenance is necessary to maintain the performances (IAQ) of the ventilation system. The third step was to collect data on costs for maintenance and complaints amongst the other 15 housing corporations. It appeared from this part of the research that very few corporations were aware of the necessity of planned maintenance and the costs for maintenance as well as the costs for complaints related to the quality of the ventilation system. Despite this it was possible to "fill" the tool with data on costs by comparing these data with more common data on *total* maintenance. The simplified tool can be used for estimating the expected maintenance and maintenance activity cycles as well as the total life cycle costs for the system, the maintenance of the system, the expected complaints and the ventilation related maintenance of the building.
The last step that is to make is linking this tool with the reliability tool of Annex 27. Svein Ruuds (1) and Johnny Kronvalls (2) work on reliability and system safety analyses is used as a basis for this.

INTRODUCTION

The objective of a tool for life cycle costs is to compare the total costs of ventilation systems and to make selections based on a cost comparison. The costs have to include:

- initial costs (investments)
- costs for maintenance of the system
- costs of maintenance of the building as a result of the ventilation system and its use.
- costs for energy.

One of the ideas was that investing more in the quality of the installation and selecting the right kind of ventilation system in relation to building properties and user characteristics could finally lead to lower maintenance costs, specially for complaint maintenance. This paper mainly focuses on the costs for maintenance of the ventilation system and ventilation related complaints in the building. Costs for energy is an output of the energy tool of Annex 27. The tool is mainly developed to be used by housing corporations and associations.
The development of the first idea for this tool was coached by chiefs of the technical department of four housing corporations in the Netherlands and representatives of the Dutch

ventilation industry (VLA). The first version of this tool was tested and applied by these housing corporations.
In order to get more data and to verify the first results a larger survey on maintenance costs was carried out amongst 15 other housing corporations. These corporations have stipulated the maintenance activities and the maintenance cycles for the ventilation system and the building itself. The first remark is that in practice there appears not to be any consensus about the required maintenance activities. Most of the corporations have their own way of planning maintenance and assessing the necessity of maintenance. There is a lack of knowledge about maintenance and its impact. Only 40 to 50 % of the required maintenance activities, as described by the Dutch ventilation industry is really carried out.
More over, only 50 % of the corporations could turn over detailed data about maintenance and complaint maintenance (= maintenance that is carried out if complaints occur and are reported to the corporation), concerning ventilation and ventilation systems. For the total maintenance activities and complaint maintenance much more data are available.
However, it was possible to draw some conclusions from this survey. One of the facts is that maintenance of ventilation systems and its costs show a relation with the total costs of maintenance.

DEFINITIONS IN RELATION TO MAINTENANCE

The following aspects in relation with maintenance are considered and definitions are used:

a. *Type of maintenance* in relation with the organisation.
The type of maintenance is determined by the way the maintenance is organised and managed. There is a difference in systematic maintenance (according to plan) and non-systematic maintenance. Systematic maintenance is based on the desired quality and need for maintenance of the building. Non-systematic maintenance is steered by signals like complaints and mutations.

b. *Maintenance activity* in relation to a technical property of a building or construction part.
Maintenance activities are the activities that are necessary during the life span of a building to maintain a certain level of quality. Each activity has its own cycle: maintaining, partial repairing, replacing.

c. *User frequency*
Building and construction parts are loaded by the environment and by daily use. This is an important factor to determine the need for maintenance. The design of the ventilation system in relation to the building must provide an optimal "load bearing" by a good selection of materials , construction and capacity. The *users frequency* is the load, in relation to the extent of use. This includes operating the ventilation provisions and cleaning.

d. *Basic quality*
There is a distinction between the basic quality of mechanical ventilation or balanced ventilation in quality of the building and quality of the ventilation system.
The basic quality of the building includes air tightness of the building envelope, location and type of supply devices in facade, ventilation windows etc. For the ventilation system the type of ventilation unit, fans, supply and exhaust air grilles and lay out and design of ducts.

e. *Maintenance classification*

The level of maintenance indicates the necessary intensity of the maintenance activity, as a result of the load by use and the design and construction. The sensitivity of a building or construction part can vary. The maintenance is classified in three categories:

- low level
- medium level (this should be according to common and accepted standards)
- high level

To determine the users frequency some indicators are used. These indicators give information about the way a user (occupant) operates and maintains ventilation provisions.

Table 1: User frequency

user frequency → **maintenance activities----------V**			**low**[1]	**medium**[1]	**high**[1]
use	installation	cleaning	regularly (monthly)	cleaning 4 times a year	not
		control and use	meet requirements	meet requirements	deranged
	building	ventilation	grilles always open	alternating grilles open	never
		cleaning grilles	cleaning regularly	cleaning not regularly	never

[1] This means: low, medium or high negative impact on the ventilation system

The maintenance activities must guarantee the original quality during the life span of the building. (Note: this definition will now be changed in "must guarantee a certain level of *reliability*").The parameters are:

- Cycle
- Costs (this means the quantity of the expected activities)
- Life cycle of construction parts (the moment of replacement)
- The chance of complaints/failures between planned maintenance activities. This is non-systematic maintenance.

Table 2: Maintenance activities

user frequency → **maintenance activities----------V**				**low**	**mean**	**high**
maintenance	installation	taking care of	measurements	standard costs/ standard cycle	standard costs/ standard cycle	standard costs/ standard cycle
			inspection	standard costs/ standard cycle	standard costs/ standard cycle	standard costs/ standard cycle
			cleaning	lower costs	reference costs	higher costs
		replace parts		longer life cycle	reference life cycle	shorter life cycle
	building	cleaning grilles		lower costs	reference costs	reference costs
		repairing grilles		longer life cycle	reference life cycle	shorter life cycle
complaints (design and construction meet requirements)				no extra maintenance	chance 1 to 30	chance 1 to 20

RESULTS OF THE SURVEY

The average complaint per dwelling per year, related to ventilation, is 0.05. The average costs for a single family dwelling are 50% higher than the costs for a multi-family dwelling. However, the average costs for repairing a complaint appeared to be much higher for multi-family dwellings with a central system. In this research the average costs for the *total* complaint/failure maintenance (i.e. all occurring complaints) are NLG 170 for single family dwellings and NLG 155 for multifamily dwellings. These costs seem to be rather low compared to known data for average costs of complaints from practice. These costs vary between NLG 150 and 400 per dwelling per year. The costs depend on the organisation, policy (relation planned and incidental or complaint maintenance) and age of installation and building.

Complaint maintenance

It appeared that the chance for a ventilation related complaint is 5 %. The chance for complaints differs with the type of ventilation system, especially between individual and central systems. This varies from approximately 7.5 % in single family dwellings to 2.5 % in multi-family dwellings with central systems. The costs for complaint maintenance per dwelling per year show big differences. According to results of this survey the average costs *per dwelling* are NLG 14. The costs for complaints in single family dwellings are a little higher than in multi-family dwellings:

- individual systems: NLG 17
- central systems: NLG 11

This leads to the following assumptions for costs per complaint:

- average: NLG 280 per complaint (= NLG 14/0.050)
- individual system: NLG 225 per complaint (= NLG 17/0.075)
- central system: NLG 440 per complaint (= NLG 11/0.025)

Relation use, basic quality and complaint maintenance

The housing corporations mentioned the following complaints and problems leading to complaint maintenance:

Table 3: Complaints and problems for different types of ventilation systems

ME in single family dwellings:	Central ME systems in multi-family dwellings	MVHR
• failing or displacement of grilles • failing of fan • smells of cooking • draught • mould grow • noise	• smells of cooking • draught • mould grow • noise	• occupants don't understand the system • wrong execution of the system • noise

Cycles for planned maintenance ME

From this research it occurs that planned maintenance of ventilation systems is quite unknown and uncommon. In order to get a definition, more close to practice, three levels are discriminated.

- Low: these are the activities, with corresponding data, carried out by the 15 housing corporations in at least more than 50 % of the cases.
- Medium: these are the activities that are carried out by at least 25% of the corporations.
- High: All required activities have to be carried out in practice, (but only less than 25% of the corporations actually do so).

In table 4 the results of the questionnaires are given. This table indicates in how many cases a maintenance activity is actually carried out (in %) and the average cycle, modified for the results in practice.

Table 4: Condensed results of research on maintenance activities

	Single family (15 corporations)		Multifamily (13 corporations)	
	cycle	% of activity that is applicable	cycle	% of activity that is applicable
- Measuring flow of grilles	7	27	5	38
- Cleaning grilles	5	38	5	38
- Measuring extract flow	8	38	7	46
- Inspecting ducts	7	23	5	31
- Cleaning ducts	14	15	13	15
- Cleaning extraction fan unit	3	54	4	85
- Replacing grilles	16	38	15	46
- Cleaning cookerhood	15	8	4	85
- Replacing cookerhood	18	23	18	23
- Replacing extraction fan unit	15	80	16	85
- Commissioning, control system	6	69	7	62

In table 5 cycles for planned maintenance are given. A comparison is made between the data as recommended by the Dutch ventilation industry and the data from this survey, representing maintenance cycles in practice.

Consequences for maintenance costs

Now the maintenance cycles are known maintenance costs can be calculated. Assumptions for these calculations are:

- considered period : 30 years
- nominal interest : 7 %
- inflation : 3.5 %
- maintenance class : as defined
- maintenance costs : Net Present Value (NPV) for complaints and planned maintenance.

Table 5: Cycles for planned maintenance; mechanical extract ventilation

Activities ↓	Number	Unit	Cycles, recommended by the Dutch ventilation industry			Cycles in practice (results of the survey)		
Maintenance level→			**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
Installation								
- Measuring flow of grilles	4	piece	4	4	4	--	6	6
- Cleaning grilles	4	piece	4	4	4	--	6	6
- Measuring extract flow	1	post	4	4	4	--	6	6
- Inspecting ducts	1	post	4	4	4	--	--	6
- Cleaning ducts	1	post	8	8	8	--	--	6
- Cleaning extraction fan unit	1	post	4	4	4	3	3	3
- Replacing grilles	4	piece	21	16	13	--	18	18
- Cleaning cookerhood	1	piece	8	4	3	--	--	6
- Replacing cookerhood	1	piece	21	16	11	--	18	18
- Replacing extraction fan unit	1	piece	21	16	11	18	18	18
- Assess control systems	1	post	4	4	4	6	6	6
Building								
- Cleaning grilles (facade)	6	piece	8	5	2	--	--	--
- Repairing grilles	6	piece	15	10	5	--	12	12
- Repairing ventilation windows	2	piece	15	10	5	6	6	6

Table 6. Maintenance costs (NPV) for three levels; mechanical extract ventilation

Type of installation	Chance complaint maintenance	Maintenance costs in NLG per dwelling in practice	Maintenance costs in NLG per dwelling (Dutch ventilation industry)
Average	low	568	842
	medium	939	1366
	high	1410	2227
Individual	low	594	
	medium	991	
	high	1488	
Central	low	541	
	medium	885	
	high	1329	

Finally the maintenance costs in practice, as provided by the 15 housing corporations, have been compared with the maintenance costs for the maintenance classes as given in table 7. Assumptions for these calculations are:

- average cycles ("medium" as in table 5)
- the range of the maintenance of single activities is corrected with the percentages, given by the housing corporations.

These calculations lead to maintenance costs for single family dwellings of NLG 1134. This value is a little higher than the costs for maintenance class "medium" from table 7 (NLG 991). This indicates that the medium level reflects realistic values from practice.
Next question is what the impact is of a "good" or a "poor" complex on the total maintenance costs. Because of the lack of information that was derived from the questionnaires (housing corporations do not know the differences in costs) it was impossible to calculate with average values. However one corporation was able to provide detailed information. If these data are used for the calculations the following results occur:

Table 7: Maintenance costs in practice for two levels of basic quality.

Building type **Basic quality**	**Single family dwellings (individual)**	**Multifamily dwellings (central)**
Good (optimal)	NLG 1532	NLG 1523
Poor (critical)	NLG 2535	NLG 2005
Difference	NLG 1003	NLG 482

For single family dwellings these results cope the calculations with the assumptions. However for multifamily dwellings there are large differences.

SIMPLIFIED TOOL FOR ESTIMATING MAINTENANCE COSTS

In four steps the maintenance costs, expressed as NPV, are estimated. Also maintenance activities and cycles are recommended to maintain these level and corresponding costs.
In step 1 the basic quality is determined by some qualitative descriptions of the installation and building qualities and properties. In step 2 the users influence or user frequency is determined, also by qualitative descriptions. If the majority of the descriptions apply to the site then the corresponding class can be used; otherwise class "average" is applicable. In step 3 the maintenance class is estimated in a graph as a function of the basic quality and user frequency. Also some cost ranges for maintenance (planned and complaints/failures) are given. In step 4 the expected costs, expressed as NPV for planned maintenance and for complaints and failures, are estimated. Also the recommended maintenance activities and cycles are given. Special attention is needed for level "low". Some of the maintenance activities are carried out by the users (as a result of a conscious behaviour, resulting in a "low user frequency") and some maintenance activities don't have to be carried out at all as a result of the basic quality of installation components. There are some differences in cycles between the tables 5 in the tool and table 5 in this paper. This is because the field research showed that some of the maintenance activities were not carried out or with a very low cycle. However we do some recommendations for (extra) maintenance activities or cycles.

REFERENCES

1. S. Ruud, Model for qualitative evaluation of reliability for ventilation systems, Working document Swedish National Testing and Research Institute, 1997.
2. J. Kronvall, System safety analysis on the performance of ventilation systems, Proceedings 17th AIVC Conference, Gothenburg, Sweden, 17-20 September 1996.
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MPLIFIED TOOL FOR ESTIMATING COMPLAINTS AND MAINTENANCE OSTS

'pe of building: Single family
'pe of ventilation system: Mechanical extract, natural supply

ecific qualities that are of concern for assessment:

ntilation system, installation:

nit:
location
accessibility
devises
uct and duct plan:
lay out of the system
devises
quality of design
quality of execution
rilles:
control possibilities
cleaning possibilities

Building:

Purpose provided openings:
- presence
- design, according to building regulations
- accessibility
- control possibilities
- cleaning possibilities

Building envelope:
- air tightness

STEP 1: Estimate the basic quality by table 1

Table 1: BASIC QUALITY

	optimal	average	critical
Installation:			
unit	• easily accessible • mounted on construction with special sound proofing provisions	• accessible • flexible mounting on construction	• difficult accessible • no sound proofing provisions for mounting
ducts	• straight duct lay-out • short duct lengths • no sharp bends, flexible tubes • air tight sealing of ducts and connections • sound proofing provisions as silencers and flexible mounting on unit	• limited flexible bends • no special sealing of ducts; connections sealed with tape	• excessive duct lengths • many bends • flexible tubes • leaky ducts • no sound proofing provisions
grilles and adjustment	• adjustment and commissioning in every dwelling • completion reports of commissioning required • cleaning possibilities without disorder the adjustment (marking or securing)	• adjustment in limited number of test dwellings • completion report of test dwellings required • cleaning possibilities with limited chance of disorder the adjustment	• no measurements and/or completion reports required • no cleaning possibilities or cleaning possibilities with chance of disorder adjustment
Building:			
air tightness	• n50 = 3.. 5	• n50 = 5...6	• no requirements

Explanation:
Classification in category "optimal" or "critical" if most of the aspects are applicable for that specific category, otherwise category "average"

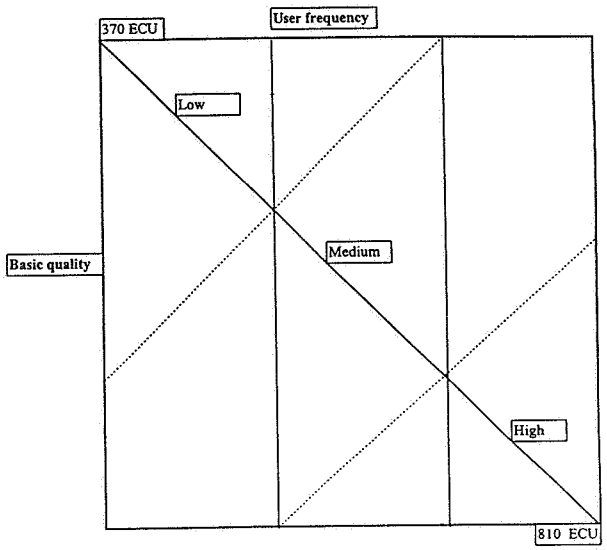
STEP 2: Estimate user frequency by table 2

Table 2: USER FREQUENCY

	low	average	intensive
Use of installation:			
instructions for use, control, maintenance etc.	personally addressed	written instructions are present	no instructions
cleaning grilles, unit	monthly cleaning	cleaning 4 x year	no cleaning
use	in accordance with manual und instructions	mostly in accordance with manual and instructions	disordering system
Building:			
ventilating, airing	conscious use of provisions	alternating use of provisions	incidental, very alternating or no use at all
cleaning vents	regularly	occasionally	no cleaning

STEP 3: After estimating the basic quality and expected user frequency the most suitable maintenance class can be established by table 3

Table 3: MAINTENANCE CLASSES



STEP 4: After estimating the most suitable maintenance class the expected maintenance costs can be estimated by table 4 and the planned maintenance activities by table 5

Table 4: EXPECTED COSTS OF MAINTENANCE expressed as LCC over 30 years (ECU)

Maintenance costs	Planned maintenance	Complaints	Total
Low	300	72	372
Medium	522	145	667
High	590	218	808

Table 5: PLANNED MAINTENANCE ACTIVITIES

ACTIVITIES	CYCLE		
Maintenance class	Low	Medium	High
Installation:			
. measuring flow capacity	--	6	6
. cleaning grilles	[1]	6	6
. inspecting ducts	18	9	6
. cleaning ducts	18	9	6
. cleaning extraction fan unit	3	3	3
. replacing grilles	--	18	18
. cleaning cookerhood	[1]	--	6
. replacing cookerhood	--	18	15
. replacing extraction fan unit	18	18	15
. assessing control system	6	6	6
Building:			
. cleaning vents/grilles	[1]	6	6
. repairing vents/grilles	--	12	12
. repairing ventilation windows	6	6	6

[1] Activity carried out by occupant