Final report, consolidated version of 22 June 2015

LOT 32 / Ecodesign of Window Products
Task 3 – User Analysis

VHK: Martijn van Elburg (main author)
ift Rosenheim: Norbert Sack, Andreas Woest
VITO: Karolien Peeters, Carolin Spirinckx

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VITO NV
Boeretang 200 - 2400 MOL - BELGIE
Tel. + 32 14 33 55 11 - Fax + 32 14 33 55 99
vito@vito.be - www.vito.be
BTW BE-0244.195.916 RPR (Turnhout)
Bank 375-1117354-90 ING
BE34 3751 1173 5490 - BBRUBEBB

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SUMMARY

This report presents the outcomes of the TASK 3 User analysis of the "ENER Lot 32" Ecodesign Preparatory study, performed by VHK and ift Rosenheim, in collaboration with VITO.

Chapter 1 and 2 give a brief introduction to the study background (Chapter 1 - Preface) and overall methodology (Chapter 2 - Introduction).

Chapter 3 is a mandatory chapter describing the direct energy consumption of windows in scope. As windows currently do not consumer direct energy (few, negligible, exceptions allowing) this chapter can be ignored.

Chapter 4 presents the indirect energy consumption of windows. It describes the main energy systems that are affected, these being the heating system, cooling system and lighting system.

It presents the main variables used to calculate the window performance. This section is directly linked to a similar section in Task 7 as both tasks are overlapping in required calculations.

Some variables, the C and Z values for use of window covering, have been modified to better reflect existing data on stock of types of window covering. It also presents a section explaining why this study could not describe the impacts on the lighting system: the main reason is that no agreed simplified method currently exists.

At the end of Chapter 4 the calculated impacts for the stock of façade windows in the residential and non-residential sector and of roof windows is presented. It shows that heating energy consumption is falling, more particularly so for residential windows. The heating performance for facade windows is expected to drop from 722 TWh_fuel eq. in 2010 of which some 90% to 80% can be allocated to residential windows to some 76 TWh_fuel eq. in 2050 (less than 80% allocable to residential windows). The cooling performance of façade windows improves from 83 TWh_fuel eq. in 2020 to 64 TWh_fuel eq. in 2050 of which some 25% to 47% can be allocated to residential windows. For roof windows the values are respectively 43 and 2 TWh_fuel eq. for heating and 14 to 11 TWh_fuel eq. for cooling.

The analysis also shows that for residential windows the cooling energy is rising. For non-residential windows and roof windows the associated amount of energy for cooling is expected to surpass that of heating energy in the period 2020-2030. This shows that although cooling demand is reduced, the heating demand is reducing faster: The heating demand can even become negative when window heating performance continues to improve (this will never happen for cooling demand, making the balance even more skewed).

The 5th and 6th Chapter deal with end-of-life aspects and (barriers and opportunities for) the local infra-structure.

Chapter 7 is a mandatory chapter dedicated to recommendations for changing scope, but none have been identified.

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VITO NV
Boeretang 200 - 2400 MOL - BELGIE
Tel. + 32 14 33 55 11 - Fax + 32 14 33 55 99
vito@vito.be - www.vito.be
BTW BE-0244.195.916 RPR (Turnhout)
Bank 375-1117354-90 ING
BE34 3751 1173 5490 - BBRUBEBB

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LIST OF ABBREVIATIONS & ACRONYMS

AP	Acidification Potential
BAT	Best Available Technology
BNAT	Best Not yet Available Technology
BOM	Bill of Materials
CA	Concerted Action
C&D	Construction and demolition waste
CENELEC	European Committee for Electro technical Standardization
CEN	European Committee for Normalisation
CPD	Construction Products Directive
CPR	Construction Products Regulation
EN	European Norm
EOL	End Of Life
EOTA	European Organisation for Technical Assessment in the area of construction products
EP	Eutrophication Potential
EPBD	Energy Performance of Buildings Directive
EPD	Environmental Product Declaration
EPS	Expanded Polystyrene
ETAG	European Technical Approval Guidelines
EU	European Union
EuP	Energy using Products
ErP	Energy related Products
FDES	Fiches de Déclaration Environnementale et Sanitaire (from the French EPD system)
GWP	Global Warming Potential
HM	Heavy Metals
IAQ	Indoor Air Quality
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
MEErP	Methodology for Ecodesign of Energy related Products
MEEuP	Methodology for Ecodesign of Energy using Products
MEPS	Minimum Energy Performance Standard
MS	Member State
NEEAP	National Energy Efficiency Action Plan
NMVOC	Non Methane Volatile Organic Compound
NZEB	Nearly Zero Energy Building
ODP	Ozone Depletion Potential

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ODS	Ozone Depleting Substance
OEF	Organisational Environmental Footprint
PEF	Product Environmental Footprint
PEFCRs	Product Environmental Footprint Category Rules
PM	Particulate Matter
POP	Persistent Organic Pollutants
POCP	Photochemical Oxidant Creation Potential
PRODCOM	PRODuction COMmunautaire
RES	Renewable Energy Sources
RoHS	Restriction of the use of certain Hazardous Substances in electrical and electronic equipment
CI/SfB	Construction Index/Samarbetskommitten for Byggnadsfrago
SME	Small and Medium sized Enterprise
TC	Technical Committee
TR	Technical Report
VITO	Flemish Institute for Technological Research
VOC	Volatile Organic Compounds

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LIST OF ITEMS OF WHICH PROPERTY RIGHTS CAN NOT BE TRANSFERRED TO THE UNION

[no items to list]

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CHAPTER 1 PREFACE

This report has been prepared by Van Holsteijn en Kemna BV (VHK) in collaboration with ift Rosenheim and the Flemish Institute for Technological Research (VITO), under the Multiple Framework Contract related to preparatory studies and related technical assistance on specific product groups (ENER/C3/2012-418-Lot 1), and in response to the Terms of Reference included in the Contract for the "Ecodesign study with regard to Windows".

The subject of this report falls under the general context of sustainable industrial policy which aims to foster the development of products with less environmental impacts.

Directive 2009/125/EC ("Ecodesign Directive") is the cornerstone of this approach as it establishes a framework for the setting of Ecodesign requirements for energy-related products (ErPs) with the aim of ensuring the free movement of these products within the internal market. Directive 2009/125/EC targets ErPs as these account for a large portion of the consumption of energy and natural resources, and a number of other environmental impacts, in the Community, in particular during their use phase.

Directive 2010/30/EC on the energy labelling of ErPs is complementary to the Ecodesign Directive as it requires (a.o.) information on the impact by these products on the use of essential resources to be provided to consumers at the point of sale.

Any measure prepared under these directives must be preceded by a study or assessment ('preparatory study') that sets out to collect evidence and stakeholder input, explore policy options and describe the recommended policy mix (ecodesign and/or labelling and/or self-regulation measures).

The product groups considered as priorities for such studies have been listed in the Working Plan 2012-2014 (established according article 16(1) of the Ecodesign Directive) and this list includes "windows". Therefore a preparatory study has been requested by the Commission.

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This preparatory study is to be executed according the Methodology for the Ecodesign of Energy-related Products (MEErP, 2011)[1] which identifies eight (1+7) tasks and shall allow stakeholder involvement. This report is the final report of Task 3 or "User Analysis" of the study.

[1] http://www.meerp.eu/ VHK BV, Netherlands and COWI, Belgium: Methodology Study Ecodesign of Energy-related Products, MEErP Methodology Report, under specific contract SI2.581529, Technical Assistance for the update of the Methodology for the Ecodesign of Energy-using products (MEEuP), within the framework service contract TREN/R1/350-2008 Lot 3, Final Report: 28/11/2011

CHAPTER 2 INTRODUCTION

This chapter introduces the objective of this "Task 3 - User analysis" and how the information presented under this task is structured.

2.1. METHODOLOGY FOR ECODESIGN PREPARATORY STUDIES

A full preparatory study follows the methodology for ecodesign of energy-related products established in 2011 (MEErP 2011) which itself is a succession of the former methodology dealing with energy-using products (MEEuP 2005) developed in 2005 to contribute to the creation of a methodology allowing evaluating whether and to which extent various energy-using products fulfil certain criteria according to Annex I and/or II of the Ecodesign Directive that make them eligible for implementing measures.

The full preparatory study is executed according seven tasks, as described below:

Task 1 – Scope (definitions, standards and legislation);

Task 2 – Markets (volumes and prices);

Task 3 – Users (product demand side);

Task 4 – Technologies (product supply side, includes both BAT and BNAT);

Task 5 – Environment & Economics (Base case LCA & LCC);

Task 6 – Design options;

Task 7 – Scenarios (Policy, scenario, impact and sensitivity analysis).

The MEErP structure recognises a split between:

- Tasks 1 to 4 (product definitions, standards and legislation; economic and market analysis; consumer behaviour and local infrastructure; technical analysis) that have a clear focus on data retrieval and initial analysis;
- Tasks 5 (assessment of base case), 6 (improvement potential) and 7 (policy, scenario, impact and sensitivity analysis) with a clear focus on modelling.

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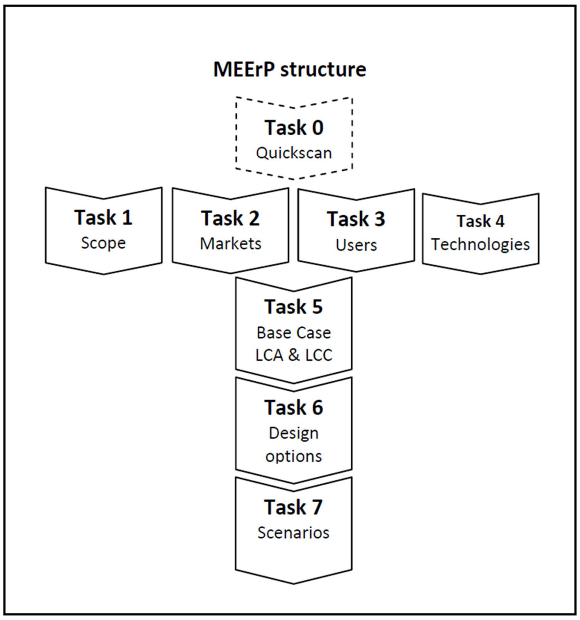
Figure 1 MEErP structure



An optional Task 0 quick scan or first product screening has been introduced in the 2011 methodology for those product groups that are characterised by a large variety of products covered by a generic product group description. It was carried out for this study as well. The findings of this Task 0 are incorporated in this Task 3 report.

Tasks 1 to 4 can be performed in parallel, whereas Task 5, 6 and 7 are sequential.

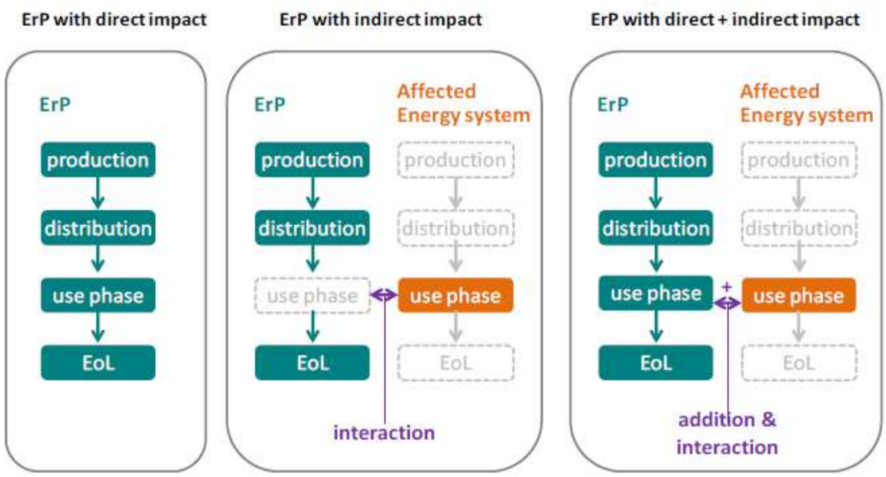
2.1.1. ENERGY RELATED PRODUCTS

The Directive 2009/125/EC defines an energy-related product as *"any good that has an impact on energy consumption during use which is placed on the market and/or put into service, and includes parts intended to be incorporated into energy-related products covered by this Directive, which are placed on the market and/or put into service as individual parts for end-users and of which the environmental performance can be assessed independently"*.

The impact on energy consumption during use of an energy-related product may take different forms and the MEErP methodology defined these as either direct and/or indirect impacts. The relevance of this lies in the analysis required and which should or should not include affected energy systems.

The MEErP introduced a grouping of energy related products into products with only direct impacts, only indirect impacts or both.

Figure 2 Three types of ErP (VHK, 2011)



Considering the above indicated grouping in MEErP of ErP products windows are an example of ErP with indirect impact.

2.2. OBJECTIVE AND STRUCTURE

The objective of this Task 3 User Analysis of "Windows" follows from the request for services ENER/C3/2012-418 LOT1/03, the subsequent proposal by the Consortium and the comments made during the preliminary discussions with the Commission.

This report will describe:

1. System aspects use phase, for ErP with direct energy consumption
2. System aspects use phase, for ErP with indirect energy consumption effect
3. End-of-Life behaviour
4. Local Infra-structure
5. Recommendations

And all the required subtasks where relevant.

Subtask 1 regarding direct energy use will be rather limited as windows are not energy using products, but mainly energy related. Still the aspect of energy consumption may be relevant when considering means for solar shading and innovative windows with special features.

→ **Objective**

The objective of Task 3 is to present an analysis of aspects related to the use of the products. The aims are:

1. Identify, retrieve and analyse data, report on the environmental & resources impacts during the use phase for ErP with a direct energy consumption effect (subtask 3.1);
2. Identify, retrieve and analyse data, report on the indirect environmental & resources impacts during the use phase for ErP with an indirect energy consumption effect, specifically (subtask 3.2);
3. Identify, retrieve and analyse data, report on consumer behaviour (avg. EU) regarding end-of-life aspects (subtask 3.3);
4. Identify, retrieve and analyse data, report on barriers and opportunities relating to the local infra-structure (Subtask 3.4);
5. Make recommendations on refined scope (Subtask 3.5).

According the MEERP study Task 3 entails the following activities:

Task 3 USERS

3.1 System aspects use phase, for ErP with direct energy consumption

Identify, retrieve and analyse data, report on the environmental & resources impacts during the use phase for ErP with a direct energy consumption effect, with impact levels subdivided in

3.1.1 a strict product/ component scope (e.g. steady state efficiency and emissions at nominal load, as in traditional standards)

3.1.2 an extended product approach: considering that the ErP will be subject to various loads/user demands; the product scope could extend to controllability (flexibility and efficiency to react to different load situations, e.g. modulating burner, variable speed drive, 'inverter'), the quality of possible controls (sensors, actuators, central processing unit) and/or the quality of auxiliary devices that may or may not be part of the ErP as placed on the market .

Examples of possibly important factors to consider, depending on the nature of the ErP, are:

- Load efficiency (real load vs. nominal capacity);
- Temperature- and/or timer settings;
- Dosage, quality and consumption of auxiliary inputs (detergents, paper- and toner use, etc.);
- Frequency and characteristic of use (e.g. hours in on, standby or off mode);
- Identification of use of second hand auxiliary inputs during product life (e.g. toner, recycled paper);
- Power management enabling-rate and other user settings;
- Best Practice in sustainable product use, amongst others regarding the items above.

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3.1.3 a technical systems approach: considering that the ErP is part of a larger product system and –through certain features of the ErP—can influence the functional performance and/or the resources use and emissions of that larger product system. E.g. central heating boiler regulation influencing indoor temperature fluctuation (discomfort), thus increasing heat demand. Other example: combination and possible synergy from combining strict ErP with other ErP (consumer electronics TV/ PC/ phone/ camera; combi-boiler with both space and hot water heating; hybrid boiler combining gas boiler with heat pump, etc.). Note that this still considers solutions of which the ErP is a physical part.

3.1.4 a functional systems approach: considering that often there are several ways to realize the basic function. E.g. water-based (hydronic) heating systems versus air-based heating systems, various modes of food preparation, etc... This analysis will often not directly affect a single Ecodesign legislation, but it is of strategic interest to guarantee coherence and consistency between the various ErP being regulated.

3.2 System aspects use phase, for ErP with indirect energy consumption effect

Identify, retrieve and analyse data, report on the indirect environmental & resources impacts during the use phase for ErP with an indirect energy consumption effect, specifically

3.2.1 describe the affected energy system(s), i.e. the systems/products whose energy consumption in the use phase of the ErP is influenced by features of the ErP

3.2.2 repeat Tasks 1.2, 1.3 (relevant standards, legislation) and Task 2 (economic and market analysis) for the affected energy system, but only related to technical parameters that relevant for the aforementioned interaction with the ErP and only in as much as they are not already taken into account in Task 1 and 2 for the ErP.

3.2.3 information retrieval and analysis of the use phase energy consumption of the affected energy system (repeat 3.1 but only for the use phase of the affected energy system).

3.2.4 Assess the interaction between the ErP and the affected energy system: describe the basic physical/chemical or other parameters and mechanisms behind the interaction, possible backed-up by statistical data or field trial or laboratory data.

3.2.5 quantify the energy use and the energy-related resources & environmental impacts during the use phase of the affected energy system(s) that is influenced by the ErP, following the outcomes of the relevant parts of Tasks 4 to 7 for the affected energy system.

3.3 End-of-Life behaviour

Identify, retrieve and analyse data, report on consumer behaviour (avg. EU) regarding end-of-life aspects. This includes:

3.3.1 Product use & stock life (=time between purchase and disposal);

3.3.2 Repair- and maintenance practice (frequency, spare parts, transportation and other impact parameters);

3.3.3 Collection rates, by fraction (consumer perspective);

3.3.4 Estimated second hand use, fraction of total and estimated second product life (in practice);

3.3.5 Best Practice in sustainable product use, amongst others regarding the items above.

3.4 Local Infra-structure

Identify, retrieve and analyse data, report on barriers and opportunities relating to the local infra-structure regarding

3.4.1 Energy: reliability, availability and nature

3.4.2 Water (e.g. use of rain water, possibilities for "hot fill" dishwashers);

3.4.3 Telecom (e.g. hot spots, WLAN, etc.);

3.4.4 Installation, e.g. availability and level of know-how/training of installers;

3.4.5 Physical environment, e.g. fraction of shared products, possibilities for shared laundry rooms, etc.

3.5 Recommendations

Make recommendations on

3.5.1 refined product scope from the perspective of consumer behaviour and infrastructure

3.5.2 barriers and opportunities for Ecodesign from the perspective of consumer behaviour and infrastructure

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The subsequent analysis will provide the Commission with information that allows scrutiny of the proposed measure(s) against article 15 criteria of the Ecodesign Directive 2009/125/EC and article 10(3.b/.c) of the Energy Labelling Directive 2010/30/EC (the "Ecodesign or Labelling point of view"). The authors of the preparatory study assume that scrutiny against the criteria as described in article 15(2/3/4/5) of Directive 2009/125/EC is adequate to fulfil the requirements of article 10(3.b/.c) of Directive 2010/30/EC.

→ **Structure**

Accordingly, the structure of this Task 3 report is based on these criteria. These tasks are covered by the study according the structure described below.

Table 1 Overview Task 3 objective and structure

Task 3 Objective	Covered by:
Subtask 3.1	Chapter 3 – Direct energy / resource consumption
Subtask 3.2	Chapter 4 – Indirect energy / resource consumption
Subtask 3.3	Chapter 5 – End-of-life aspects
Subtask 3.4	Chapter 6 – Local infrastructure
Subtask 3.5	Chapter 7 – Recommendations

CHAPTER 3 DIRECT ENERGY CONSUMPTION

3.1. DIRECT ENERGY CONSUMPTION

As the MEErP is a generic methodology, applicable to all energy related products, it requires an assessment of the energy use by products where relevant.

In the case of windows however, the products are seldom energy-using.

Only in cases of windows with automation for opening and closing or controlling shading devices or in cases of windows in which solar photovoltaic panels are integrated, or that can modify light transmittance by electro chromic effects or are equipped with IR heater surfaces, some direct energy consumption (or even production) may be relevant, but all these examples are certainly not standard products and their relevance for an overall energy assessment is judged to be very limited.

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CHAPTER 4 INDIRECT ENERGY CONSUMPTION

4.1. Introduction

According the MEErP methodology this section is to identify, retrieve and analyse data, report on the indirect environmental & resources impacts during the use phase for ErP with an indirect energy consumption effect, specifically:

1. the affected energy system(s), i.e. the systems/products whose energy consumption in the use phase of the ErP is influenced by features of the ErP
2. description of relevant standards, legislation and economic and market analysis (Task 2) for the affected energy system, but only related to technical parameters that are relevant for the aforementioned interaction with the ErP and only in as much as they are not already taken into account in Task 1 and 2 for the ErP.
3. Information retrieval and analysis of the use phase energy consumption of the affected energy system.
4. Assessment of the interaction between the ErP and the affected energy system: describe the basic physical/chemical or other parameters and mechanisms behind the interaction, possible backed-up by statistical data or field trial or laboratory data.
5. Quantification of the energy use and the energy-related resources & environmental impacts during the use phase of the affected energy system(s) that is influenced by the ErP, following the outcomes of the relevant parts of Tasks 4 to 7 for the affected energy system.

4.2. Affected energy systems

The energy systems of which the energy consumption is affected by windows are:

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1. space heating systems;
2. space cooling systems;
3. lighting systems.

In Section 4.5 the interaction between windows and these affected energy systems is explained further.

4.3. Standards, legislation and other relevant parameters of affected systems

The above mentioned energy systems are described extensively in various preparatory studies and for several products regulations are prepared or even already adopted.

Standards are described in the supporting ecodesign preparatory studies and the (proposed) regulations introduce new, most relevant legislation. The relevant parameters are identified in the documents. The table below gives an overview.

Table 2 Overview of studies and legislation of related energy systems

Product groups	Preparatory Study	Regulatory document status	Mandatory from	Relevant parameter
SPACE HEATING SYSTEMS				
Lot 1 Boilers and combi-boilers	Completed	Reg. 813/2013	26.09.2015	Seasonal space heating efficiency
Lot 15 Solid fuel small combustion installations	Completed	Draft Regulation		Seasonal space heating efficiency
Lot 20 Local room heating products	Completed	Draft Regulation		Seasonal space heating efficiency
Lot 21 Central heating products using hot air to distribute heat	Completed	Working document		Seasonal space heating efficiency
SPACE COOLING SYSTEMS				
ENTR Lot 6 Air-conditioning and ventilation systems	Completed	Draft Regulation		Seasonal space cooling efficiency
Lot 10 Room air conditioning	Completed	Reg. 206/2012	30.03.2012	Seasonal space cooling efficiency
LIGHTING SYSTEMS				
Lot 19 Domestic lighting part I "non-directional lamps"	Completed	Reg. 244/2009Amendm. 859/2009	01.09.2009	Lamp efficacy and energy consumption
Lot 19 Domestic lighting part II "directional lamps"	Completed	Reg. 1194/2012	01.09.2013	Lamp efficacy and energy consumption
Lot 8 Office lighting	Completed	Reg. 245/2009Amendm. 347/2010	13.04.2010	Lamp efficacy and energy consumption

4.4. USE PHASE ENERGY CONSUMPTION OF AFFECTED SYSTEMS

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According the MEErP study[2] the affected energy systems have energy consumption as follows.

Table 3 Energy consumption of affected energy systems

Energy consumption 2007		Remark
space heating	13 225 PJ/yr	This comprises all heating/cooling/lighting systems, both central and decentral, electric or fuel fired (heating or cooling systems), and for residential, commercial, industrial, etc.
space cooling	165 TWh/yr = 1 485 PJ/yr	
lighting (all categories)	340 TWh/yr = 3 060 PJ/yr	

In this study additional sources have been consulted. The 2010 residential + non-residential heat demand of 2860 TWh_heat (some 10 296 PJ), reducing to 2406 TWh_heat in 2050, is kept identical to the heat demand identified in the EU study "Average EU building heat load for HVAC equipment" (p. 64)[3]. The 2010 cooling demand of 219 TWh_cool (some 788 PJ), growing to 352 TWh_cool in 2030, is equal to the cooling demand identified in the "Ecodesign Impact Study"[4], also referenced in the "Average EU building heat demand" study.

Table 4 Energy consumption of affected energy systems according "Average EU building heat load"

	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020	2030	2040	2050
HEATING DEMAND																

[2] MEErP 2011

[3] Average EU Building Heat Demand, Aug. 2014: https://ec.europa.eu/energy/sites/ener/files/documents/2014_final_report_eu_building_heat_demand.pdf

[4] Ecodesign Impact Accounting, June 2014: https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf

		1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020	2030	2040	2050
residential	TWh_heat	577	638	704	778	860	950	1049	1159	1280	1566	1619	1725	1796	1777	1654	1451
non-residential	TWh_heat	380	420	464	512	566	625	690	762	842	1030	1065	1135	1182	1169	1088	955
COOLING DEMAND																	
residential	TWh_cool	0	0	0	0	0	0	0	1	1	2	8	27	46	67	74	79
non-residential	TWh_cool	0	0	0	1	2	3	7	13	27	54	102	193	260	285	284	276

4.5. INTERACTION OF WINDOW PRODUCTS AND AFFECTED SYSTEMS

The performance of a window, and therefore its effect on related energy systems is first and foremost determined by how this window interacts with its environment, which is the building itself.

Method for calculating performance

The actual calculation method applied is described in TASK 7, as part of establishing the energy performance of windows using ABC/XYZ values. This approach was preferred over the rather fixed calculation of window performances using the 'adiabatic approach' as applied in TASK 4. The main reason is that the ABC/XYZ approach allows more flexibility for changing parameters, such as typical use-aspects these being the use of shutters and other shading devices in summer and winter.

The values proposed for establishing the performance of windows are the same values as to be used in the Business-as-usual scenario in TASK 7 (as the effects calculated in TASK 3 should match those calculated in TASK7). Furthermore we preferred to use the same values as basis for environmental analysis in TASK 5 and cost analysis in TASK 6, so that the same performance of windows is being discussed.

The ABC/XYZ values that have been defined in TASK 7 relate to either a calculation using the 'single room' as basis, or the '(single) family house' as basis. Both approaches have their advantages and disadvantages, as explained in TASK 7. In general one can say the 'single room' is more applicable to spaces that have less transmission losses, and the 'family house' is more applicable to spaces with higher transmission losses.

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For the purpose of this TASK 3 (and related TASK 5, 6 and 7 analysis) we have decided to use values established by both approaches, whereby the 'single room' based ABC/XYZ values apply to a residential apartment, and the 'family house' based ABC/XYZ values apply to residential family houses (with a ground floor and roof).

For roof windows we have decided to use only ABC/XYZ values established with the 'single room' approach as overheating calculations are usually performed on the basis of the most critical room and do not assume the excess heat is completely distributed over the entire building.

Following a weighing of apartment dwellings versus family dwellings, the following values have been used for the calculation of performances:

Table 5 ABC/XYZ values for assessment in TASK 3

Facade windows	North	Central	South	Roof windows	North	Central	South
A	98	61	18	A	86	49	9
B	225	196	193	B	156	150	90
C (22/6)	0.35	0.37	0.42	C (22/6)	0.35	0.36	0.38
X	0.3	0.1	-4.3	X	1.3	1.2	-3.0
Y	17	44	304	Y	56	127	659
Z	0.69	0.54	0.66	Z	0.75	0.75	0.88
Note that factor C and Z are corrected by factors to better align the results to data regarding stock and assumptions regarding use of window covering in heating and cooling season – see section 4.5.1							

The C and Z values will be modified to reflect a more realistic use of adaptable devices (rollers, blinds) in the heating season and the cooling season, as the boundary conditions for C as selected assume shutters, with additional thermal resistance, are activated from 22:00 to 06:00 , and that shading devices are activated in the cooling season when the irradiance exceeds 300 W/m^2 (and the external temperatures is above a given setpoint).

4.5.1. INTERACTION WITH SHUTTERS

→ **Heating performance**

The use of certain types of window covering can improve the heating energy performance of windows as for example a shutter may (depending on type and use) add extra thermal insulation during the heating season when activated (closed). This is reflected in the calculation of the effective thermal transmittance of the window, which is calculated as:

Equation 1

$$U_{W,eff} = (1-C)\cdot U_W + C\cdot U_{W,S}$$

Equation 2

$$U_{W,S} = \left(1/U_W + \Delta R\right)^{-1}$$

In the basic assessment (see also TASK 7) a shutter with ΔR = 0.17 (m^2K)/W is used, which is the average for roller shutters of wood and plastic without foam, as shown in the table below.

Table 6 ΔR of various window coverings[5]

	Typical thermal resistance of shutter (m^2K)/W	Additional thermal resistance at specific air permeability of the shutters (m^2K)/W		
		high or very high air permeability	average air permeability	Tight or low air permeability
Roller shutters of aluminium	0.01	0.09	0.12	0.15
Roller shutters of wood and plastic without foam filling	0.10	0.12	0.16	0.22
Roller shutters of plastic with foam filling	0.15	0.13	0.19	0.26
Shutters of wood, 25-30 mm thickness	0.20	0.14	0.22	0.30

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Based on information from a study into the benefits of thermal insulation by 'window covering'[6] values for external roller blinds (average ΔR = 0.10 (m^2K)/W) and for indoor blinds (average ΔR = 0.07 (m^2K)/W) were retrieved.

When applied to ES-SO's list of sales of window coverings (TASK 2) and with correction to share in stock, plus estimates for missing types of window covering, the average 'stock' ΔR is 0.035 (m^2K)/W.

Table 7 ΔR in (m^2K)/W of stock window

	ΔR		Share of stock
Awnings (Folding arm, terrace, …)	(zero)	(estimate)	1%
External roller blinds (markisolette, …)	0.10		1%
External venetian blinds	0.05	(estimate)	2%
Internal blinds (made to measure)	0.07		16%
Panel shutters (sliding, hinged, …)	0.05	(estimate)	2%
Roller shutters	0.17		12%
No (known) window covering	(zero)		66%

[5] Source: ISO 10077-1, Table J.2

[6] L.Bakker, D.vanDijk, "Besparingen op verwarminsgenergie door thermische isolatie van zonweringen" (TNO 2015 R10396), TNO Delft, March 2015

Average window covering	0.035	100%

The $U_{W,eff}$ for a fairly standard window in Central Europe (assuming U_W=1.7 W/(m^{2}K), ΔR=0.17 (m^{2}K)/W, C=0.38) is 1.56 W/(m^{2}K). With the average stock ΔR=0.035 (m^{2}K)/W the $U_{W,eff}$ is 1.66 W/(m^{2}K. Now, by multiplying the C value with a factor 0.25, the same stock $U_{W,eff}$ is 1.66 W/(m^{2}K) is achieved with ΔR=0.17 (m^{2}K)/W. So, one can correct for the stock ΔR of 0.035 by multiplying the C = 0.38 by 0.25 (C is then 0.095).

This still assumes the shading is used from 22:00 to 06:00. If we assume the 8% of coverings with motor use the devices correctly (C=0.38), and of the remaining 92% only half uses the device half correct (C=0.19), and the rest uses the device correctly again half of that (C=0.095) then the overall combined C is 0.16, which is a correction factor 0.43. Combined with the correction 0.25 for ΔR of the covering, the overall C=0.38 should thus be corrected by (0.25*0.43) is 0.11.

For the sake of simplicity the use of window covering is assumed to be the same for residential and non-residential windows, and for façade and roof windows.

Note that this assessment only applies to window coverings being used to avoid heating loads. It does not consider the use of coverings for other reasons such as reduction of glare, privacy, anti-burglary, noise or light reduction, etc. – there are numerous reasons people buy and use window covering devices.

→ **Cooling performance**

The energy performance for cooling is calculated as:

Equation 3

$$P_{E,C,W} = -X \cdot (U_W + H_{ve,w}) + Y \cdot g_{W,eff}$$

The use of window covering such as shading devices can improve the cooling energy performance of windows as for example a shutter may (depending on type and use) avoid solar irradiance to enter the building, causing or increasing the need for (artificial) cooling during the cooling season. This is reflected in the calculation of the effective g-value of the window, which is calculated as:

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Equation 4

$$g_{W,eff} = (1 - F_F) \cdot [(1 - Z) \cdot g + Z \cdot g_t]$$

The g_t is a function of the Fc and g (or vice versa).

Equation 5

$$F_c = \frac{g_{tot}}{g}$$

With given F_c values, the g_t can be calculated, as shown below.

Table 8 Overview of F_c and g_t for various shading devices and windows

	Solar shading device	Awnings (Folding arm, terrasse, …)	External roller blinds (markisolette , …)	External venetia n blinds	Internal blinds (made to measure)	Panel shutter s (sliding, hinged, …)	Roller shutter s
F_c (average)	if g>0.40	0.45	0.2	0.15	0.75	0.1	0.1
	if g<0.40	0.55	0.25	0.2	0.6	0.15	0.15
	g (glazing)	g_t (glazing + shading)					
01_single	0.85	0.38	0.17	0.13	0.64	0.09	0.09

	Solar shading device	Awnings (Folding arm, terrasse, …)	External roller blinds (markisolette , …)	External venetian blinds	Internal blinds (made to measure)	Panel shutters (sliding, hinged, …)	Roller shutters
02_double IGU, standard	0.78	0.35	0.16	0.12	0.59	0.08	0.08
03_double IGU, lowE, argon	0.65	0.29	0.13	0.10	0.49	0.07	0.07
04_double IGU,lowE, argon, impr	0.6	0.27	0.12	0.09	0.45	0.06	0.06
05_triple IGU, lowE, argon	0.55	0.25	0.11	0.08	0.41	0.06	0.06
06_triple IGU, lowE, argon, impr.	0.6	0.27	0.12	0.09	0.45	0.06	0.06
07_coupled	0.58	0.26	0.12	0.09	0.44	0.06	0.06
08_quadruple	0.47	0.21	0.09	0.07	0.35	0.05	0.05
09_as 02, solar	0.35	0.19	0.09	0.07	0.21	0.05	0.05
10_as 04, solar	0.35	0.19	0.09	0.07	0.21	0.05	0.05
11_as 06, solar	0.35	0.19	0.09	0.07	0.21	0.05	0.05

In the basic assessment a shading device with a F_c=0.1 is used, which gives a g_t = 0.07 if this is a roller shutter for a standard LowE window (type 3). The average stock window however has a F_c which is closer to 0.80, as calculated in accordance with the table below.

Table 9 F_c of stock window

	Share of stock	Fc
Awnings (Folding arm, terrace, …)	1%	0.45
External roller blinds (markisolette, …)	1%	0.20
External venetian blinds	2%	0.15
Internal blinds (made to measure)	16%	0.75
Panel shutters (sliding, hinged, …)	2%	0.10
Roller shutters	12%	0.10
No (known) window covering	66%	1
Average window covering	100%	0.80

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With average stock F_c =0.80 and average stock g = 0.7 (U_W of stock 2020 is 2.3 W/(m^2K), slightly below simple glazing U_W 2.8 W/(m^2K), average g is assumed to be 0.7) the average stock window g_t is 0.56.

The $g_{W,eff}$ for a fairly standard window in Central Europe with optimal shading F_c=0.1 and assuming g=0.65, g_t = 0.07, C=0.57) is 0.34. With the average stock g_t=0.56 the $g_{W,eff}$ is 0.62. This $g_{W,eff}$ can also be achieved by correcting the C for g_t = 0.07 by correction factor 0.25.

This still assumes the shading is activated when irradiance exceeds 300 W/m^2 (during cooling period). If we assume (as for heating performance) the (users of the) 8% of windows with coverings with motor use the shading devices correctly and of the remaining 92% only half uses the device half correct and the rest uses the device correctly again half of that then the overall correction factor is 0.43. Combined with the correction 0.25 for g_t of the covering, the overall C=0.57 should thus be corrected by (0.25*0.43) is 0.11.

For the sake of simplicity the use of window covering is assumed to be the same for residential and non-residential windows, and for façade and roof windows.

Note that this assessment only applies to window coverings being used to avoid cooling loads. It does not consider the use of coverings for other reasons such as reduction of glare, privacy, anti-burglary, noise or light reduction, etc. – there are numerous reasons people buy and use solar shading devices.

4.5.2. Orientation of window

The ABC/XYZ values selected assume a uniform distribution of windows per orientation. The limited amount of data available on window orientation suggests that windows are indeed fairly evenly distributed.

Table 10 Average window orientation[7]

Orientation	EAP	SENVIVV
North	11%	10%
NW	13%	9%
West	12%	14%
SW	13%	14%
South	15%	15%
SE	15%	14%
East	12%	15%
NE	10%	10%

On the basis of this limited survey, one may conclude a very small higher share of windows facing W-SW-S-SE-E, but the differences are that small that the average window can be assumed to have an orientation with equal weighting across all orientations.

4.5.3. HEATING AND COOLING SYSTEMS

The technical properties of the windows, together with the actual installation and the relation to the building in which it is installed, determine the annual energy balance of the window. This balance represents the trade-off between heat losses and heat gains, including unwanted heat gains that require cooling energy.

The relations between window characteristics and the building energy needs are described in:

- EN ISO 13790 Energy performance of buildings —Calculation of energy use for space heating and cooling, and;
- ISO 18292 Energy performance of fenestration systems for residential buildings — Calculation procedure (of the energy balance for windows).

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These standards have been introduced already in TASK 1.

Several boundary conditions need to be defined (or assumed) in order to complete the calculations. The following boundary conditions have been defined for the calculation:

External Climate

- External Temperature T_e
- Solar Irradiance (N;W;E;S)
- pressure difference Δp to calculate the volume flow caused by infiltration of the window

Internal Climate

- Temperature Limit for Heating
- Temperature Limit for Cooling

Building

- Dimensions
- Heat Capacity (thermal mass)
- U-value of the envelope (exterior wall, roof, floor)
- Orientation of the windows
- Area of the windows
- slope of roof windows

Other parameters

- ventilation rate n
- increased ventilation rate (ventilative cooling)
- internal loads
- set points of activation for increased ventilation rate
- set points of activation of the sun shading
- usage of the building (e.g. 24h/7 days a week

[7] Source: Study conducted by BBRI, commissioned by VELUX A/S

The calculations rely on the use of 'reference buildings' such as the 'single room' and the 'family house'. These reference buildings are described in more detail in TASK 7. The calculations have been performed on a simplified hourly basis, using a dynamic model (in accordance with ISO 13790).

On the basis of these calculations ABC and XYZ values have been defined that allow calculating the performance of a window using generic equations, in combination with the main window characteristics. The process has been described in TASK 7, as the ABC/XYZ values have been identified in this TASK 7 report.

Table 11 ABC and XYZ values used for assessment

Facade windows	North	Central	South	Roof windows	North	Central	South	Remarks
A-uni	98	61	18	**A-uni**	86	49	9	
B-uni	225	196	193	**B-uni**	156	150	90	
C-set/rise	0.04	0.04	0.05	**C-set/rise**	0.04	0.04	0.04	original value corrected by 0.11
X-uni	0	0	-4	**X-uni**	1	1	-3	
Y-uni	17	44	304	**Y-uni**	56	127	659	
Z-uni	0.08	0.06	0.07	**Z-uni**	0.08	0.08	0.10	original value corrected by 0.11

Using the ABC/XYZ values presented in the first section of this Chapter, the window energy performance was calculated as follows.

Table 12 Energy performances of façade and roof windows for heating and cooling, as used in Task 3

Performance (kWh/m^2*yr)	HEATING			COOLING		
Window type:	North	Central	South	North	Central	South
single	563.2	316.9	12.8	7.3	24.1	200.4
double	194.6	90.5	-47.2	7.7	22.5	169.6
double, lowE	78.3	23.2	-54.7	6.7	18.8	137.8
double, lowE, impr.	47.5	6.0	-55.0	6.3	17.4	126.2
triple	26.3	-5.2	-53.6	5.8	16.0	115.1
triple, opt.	-1.0	-24.1	-63.9	6.4	17.5	124.1
coupled 1+2	21.6	-9.3	-57.6	6.1	16.9	121.0
coupled 2+2	0.1	-18.4	-49.9	5.0	13.7	97.6
double, solar (as 2)	262.4	149.5	10.9	3.0	10.0	84.7
double, solar, lowE (as 4)	86.9	40.3	-21.2	3.5	10.2	76.9
triple, solar (as 6)	38.4	10.2	-30.1	3.7	10.2	74.7
roof_03 (Uw 1.3, g 0.6)	59.1	7.9	-24.8	20.0	47.9	258.8
roof_04 (Uw 1.0, g 0.5)	44.5	3.9	-21.1	16.8	39.6	95.7
roof_05 (Uw 0.8, g 0.5)	27.5	-5.8	-22.9	16.8	16.6	95.1
roof_06 (Uw 1.3, g 0.35)	86.4	34.2	-9.0	4.5	12.7	64.3

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The heating performance represents the energy required for heating, per 1 m^2 of the window. The cooling performance represents the energy required to cool the room, per 1 m^2 of the window. A lower value is better.

The lighting energy could not be calculated using this simplistic approach. The following section explains why.

4.5.4. LIGHTING SYSTEMS

Especially in commercial buildings lighting is a major energy consumer and a primary target for reducing building energy consumption. Since several years already the glazing industry is devoting considerable efforts to improving the thermal insulation and/or the g-value, without reducing the daylight factor[8].

[8] *G. Baldinelli, F. Asdrubali, C. Baldassarri, F. Bianchi, F. D'Alessandro, S. Schiavoni, C. Basilicata "Energy and environmental performance optimization of a wooden window: A holistic Approach". Energy and Buildings 79 (2014) 114–131.*

Despite these ongoing efforts and recognition of lighting being a main energy aspect, there is currently no universally agreed method to directly translate changes in window light transmittance to changes in energy consumption by building lighting systems.

Generally speaking, the calculation of artificial lighting needs to meet a required lighting level in a building is a highly complex exercise, that not only requires exact inputs in building physical appearance (façade geometry, orientation, inclination, etc.), but also inputs related to interior properties (reflectance of the interior walls, ceiling, furniture, all play a role), user behaviour (anti-glare measures, required lighting (lux) levels) and that of the lighting system (luminaires, bulbs, but also the control system), to name just the more important ones.

The complexity of the interactions necessitates the use of modelling and simulation tools to dynamically analyse the effects of the relationships.[9]

There are several commercial software packages that specifically address the above mentioned complexity, such as COMFEN (EnergyPlus, Radiance™ and WINDOW), EFEN (DesignBuilder), Daylight1-2-3 (NRC), SPOT (AEC), Ecotect (Autodesk), and the MIT Design Advisor (MIT). The dynamic codes requires a more detailed modelling configuration and allow to reproduce more accurately the real behaviour of the building, including how its lighting needs are met[5]

The early design energy modelling tool (COMFEN) was developed by Lawrence Berkeley National Laboratory (LBNL) to help make informed decisions about building facade fundamentals by considering the design of the building envelope, orientation and massing on building performance. COMFEN focuses on the concept of a "space" or "room" and uses the EnergyPlus, and RadianceTM engines and a simple, graphic user interface to allow the user to explore the effects of changing key early-design input variables on energy consumption, COMFEN 3.0 - Evolution of a Commercial Façade and Fenestration Early Design Tool Page | 2 peak energy demand, and thermal and visual comfort. Comparative results are rapidly presented in a variety of graphic and tabular formats to help users move toward optimal façade and fenestration design choices."

COMFEN 3.0 - Evolution of an Early Design Tool for Commercial Façades and Fenestration Systems. Lawrence Berkeley National Laboratory, Building Technologies Department, Berkeley, CA. STEVE SELKOWITZ, ROBIN MITCHELL, MAURYA MCCLINTOCK, DANIEL MCQUILLEN ANDREW MCNEIL, MEHRY YAZDANIAN.

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Such software tools, notwithstanding the benefits of using this while designing specific buildings and (lighting) systems, cannot be used for the purpose of legislating windows. For possible measures under Ecodesign and/or Energy Labelling, the legislator needs to build upon simple and robust methods to transform basic window properties into a performance / ranking / score that can be used for regulating the product. Having each supplier that places products on the market to use such a complex modelling tool is not desired, and additionally, the tool would then also need to be 'certified' for this use for making claims with legal implications, which currently no tool is.

→ **Daylight potential factor**

There is a method defined in ISO 18292 (international standard for the energy balance of windows) allowing to calculate a so called 'daylight potential'.

"The daylight potential of a fenestration system indicates its potential to supply a building with daylight and depends on the visible transmittance, the glazing to fenestration system area ratio and on the view factor from the glazing to the sky and the ground. The latter parameter is used to determine the effect of different fenestration system slope angles."

According to ISO 18292, the daylight potential of the fenestration system as a building component is treated as independent of parameters such as the fenestration system height over floor, building overhangs and of the interior of the building. These all affect the daylight performance in practical situations.

The daylight potential is calculated by the following equation:

Equation 6

$$\tau_{DP} = \tau_v (F_{g-s} + r \cdot F_{g-g}) \cdot (1 - F_F)$$

Where

τ_v is the light transmittance of the glazing (determined according to EN 410)

[9] *Steve Selkowitz, Robin Mitchell, Maurya Mcclintock, Daniel Mcquillen Andrew Mcneil, Mehry Yazdanian "COMFEN 3.0 - Evolution of an Early Design Tool for Commercial Façades and Fenestration Systems". Lawrence Berkeley National Laboratory, Building Technologies Department, Berkeley, CA.*

$F_{g\text{-}s}$ is the view factor form the glazing to the sky

$F_{g\text{-}s}$ is the view factor form the glazing to the ground

r is the albedo of the ground (r=0,2 is normally used)

F_F is the frame fraction of the window

All of these characteristics are without dimension. The relationship between the view factors and the installation angle of the window are given below

Equation 7

$$F_{g-s} = (1 + \cos\gamma)/2$$

$$F_{g-g} = (1 - \cos\gamma)/2$$

Where

γ is the angle between the glazing plane and the horizontal, where γ = 0°

With an albedo r=0,2 the daylight potential for facade windows (vertical installation) therefore transforms to

Equation 8

$$\tau_{DP,facade} = 0.6 \cdot \tau_v \cdot (1 - F_F)$$

Assuming a representative inclination for roof windows of 40° the daylight potential factor for roof windows is

Equation 9

$$\tau_{DP,roof} = 0.93 \cdot \tau_v \cdot (1 - F_F)$$

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If the window comprises a movable shading device that shades solar radiation (e.g. venetian blind, shutter), values for the complete dynamic range (fully open and fully closed) shall be given. The daylight potential of a window in combination with a shading device therefore is

Equation 10

$$\tau_{DP,t} = \tau_{v,t}(F_{g-s} + r \cdot F_{g-g}) \cdot (1 - F_F)$$

Where

τ_v is the total light transmittance of the glazing in combination with the solar protection device(determined according to EN 13363-1 or EN 13363-2)

Generally the following typical τ_v values would apply to windows with a given g- or gt-value.

Table 13 Typical g- and τ_v values of windows

	g-value	τ_v
no shading	g = 0.78	0.82
	g = 0.62	0.80
	g = 0.35	0.65 (max 0.70)
with shading	gt = 0.1 (g = 0.6)	0.15

It is suggested in TASK 7 to include this daylight potential factor in the technical fiche of Energy Labelling for Windows.

→ **Artificial lighting needs**

But how does this daylight potential factor influence artificial lighting energy needs? As already explained above, the factor τ_v appears to be only a small parameter in the more specific and complicated calculation of artificial lighting needs of buildings.

Just to show the complexity of such an assessment the draft standard DRAFT prEN 15193-1 rev (August 2014) Energy performance of buildings - Module M9 – Energy requirements for lighting - Part 1: Specifications, drawn up by the Technical Committee CEN/TC 169, presents a method.

The 'metered' and 'quick' method does not include window properties as variables and are therefore inadmissible. If the influence of windows is to be included, then only the 'detailed' method remains (Clause 6).

In order to calculate the lighting energy needs according the detailed method, one starts with the lighting power installed and how long the lighting is turned 'on'. This sounds easier than it actually is: Lighting power is determined by lamp installed power and number of lamps, plus corrections for loss of light output. The lamp power is partly determined by the required lux level, which are quite different per building and task executed in the space lit. An occupancy dependency factor is used to correct for actual need for light, during the day. This is again different for task areas, or circulation areas, control systems (presence detection yes/no, turn lights on/off in whole room or just part, etc.).

Then follows the daylight dependent factor which is used to calculate which share of lighting needs is met by artificial lighting, assuming the other share is met by daylight. First a correction is made for areas with daylight access and areas without. This depends also on the space height and depth being illuminated. The calculation of the amount of daylight available is influenced by the transparency index, space depth index and a shading index. A daylight supply factor is used to correct for use of shading / glare protection devices, the ratio between direct and indirect light, and – here it finally is! – a correction for the amount of daylight actually passing the glazed area of the window, which is based on total light transmittance τ_v (see above) , but also a correction for pollution, reduction for non-vertical light, reduction for frames and divisions.

The total artificial lighting energy is then also corrected for overdesign / maintenance factors, which is again dependent on lamp lumen maintenance factor, lamp survival factor, and luminaire maintenance and room surface maintenance factors.

The above makes clear that if the actual building, its components and its use are known, the calculation of energy demand for lighting can be performed, and the influence of the total light transmittance of the glazing may be included, but it requires consideration of many parameters that are not known and/or difficult to assess. In the assessment of space heating and cooling energy many of such factors (distance from window, installed power) are much less relevant. Lighting is much more than heating or cooling instantaneous.

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In addition, several stakeholders have repeatedly argued (see also the minutes of the two stakeholder meetings, posted on the project website) that if an energy label for windows is recommended, this label should not apply to non-residential applications for two reasons mainly: 1) the differences in non-residential applications are much larger than in residential applications and general conclusions would not hold; 2) most window replacement in the non-residential sectors is guided or handled by building professionals, and the requirements are often much stricter (i.e. large renovations).

Considering the above it is concluded that the calculation of changes in lighting energy needs as a result of changes in window properties is highly complex and the final result (a label with lighting energy considered) is considered by most stakeholders of limited relevance to the sector(s) where lighting is a major energy consumer (non-residential sector).

Nonetheless, the consideration of prEN 15193-1:2014 does show that the influence of applying solar control glazing (low g-value glazing) is most likely of less influence than applying solar shading devices with low g_t values: When applying solar control glazing , the total light transmittance may be reduced from 0.8 to 0.65, a reduction of some 19%. But if (very good) solar shading is used, with a g_t of 0.1, the total light transmittance may be reduced by 80% (if fully closed). Of course other g_t values can be achieved if the shade is moveable, or with a different kind of shade, with less pronounced effects on total light transmittance.

And the relation to cooling energy should be considered as well, as a lower g(t) reduces cooling loads, but increases artificial lighting loads, which again leads to higher cooling loads. This effect could not be modelled within this study.

4.6. QUANTIFICATION OF INDIRECT ENERGY IMPACT ON AFFECTED ENERGY SYSTEMS

This section shows the main outputs of the calculation model, for three sectors: residential, non-residential and roof windows. The calculated impact on related (affected) energy systems is shown in the table below.

[Note! the data for the non-residential sector are not validated. The outcomes remain indicative only]

Table 14 Impacts on affected energy systems (heating and cooling), in TWh_fuel/yr

Impact (TWh_fuel/yr)	1990	2000	2010	2020	2030	2040	2050
residential / heating	1308	985	642	335	153	84	59
residential / cooling	3	8	21	23	28	29	30
non-residential / heating	130	108	80	50	30	21	17
non-residential / cooling	48	68	62	49	42	38	34
roofwindows / heating	97	75	54	30	15	9.2	6.6
roofwindows / cooling	6	10	14	13	12	11.6	11.0

Figure 3 Impacts on affected energy systems 1990-2050, TWh_fuel/yr

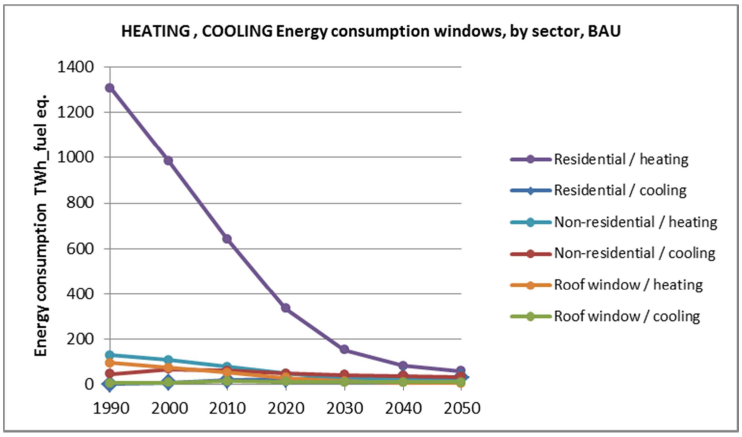

Figure 4 Close-up 2030-2050 Impacts on affected energy systems, TWh_fuel/yr

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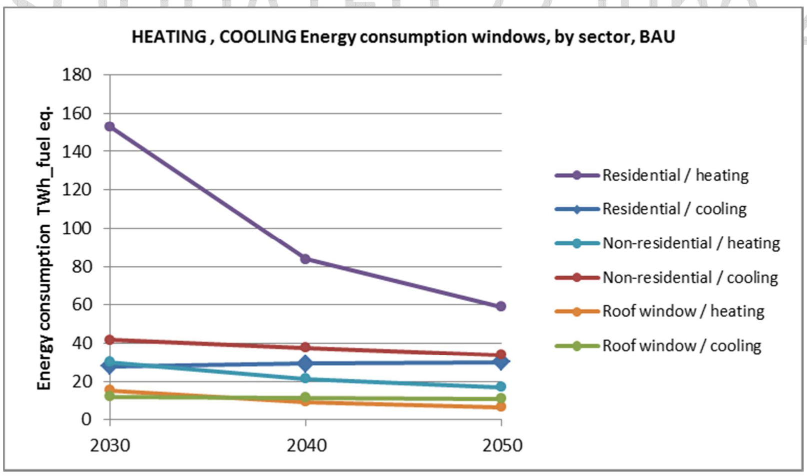

4.6.1. MODEL OUTPUTS FOR RESIDENTIAL, NON-RESIDENTIAL AND ROOF WINDOW SECTOR

The table below presents the annual sales, stock and impacts / related energy consumption (accordance with MEERP 2011 requirements) for the BAU scenario / residential sector.

Table 15 BAU Scenario / residential

OUTPUT Residential		1990	2000	2010	2020	2030	2040	2050
Sales new build	'10^6 m2/yr	68	44	48	47	45	44	43
Demolished	'10^6 m2/yr	-12	-15	-19	-24	-34	-36	-41
Sales replacements	'10^6 m2/yr	87	94	102	107	110	112	113
Total stock	'10^9 m2/yr	3.5	3.8	4.1	4.3	4.4	4.5	4.5
Heating energy	TWh_fuel	1308	985	642	335	153	83.8	58.9
Cooling energy	TWh_fuel	3	8	21	23	28	29.1	30.1
Final energy windows	TWh_fuel/yr	1311	993	663	358	181	113	89
	PJ_prim	4719	3576	2387	1287	651	407	320
GHG Emissions	Mt CO2 eq./yr	261	191	122	65	32	20	15
Mat. in	kt	3190	2988	3480	3678	3790	3883	3937
Mat. out	kt	-1948	-2295	-2660	-3064	-3459	-3607	-3761
Indirect energy	TWh_fuel	24	26	30.0	27.0	20.8	15.8	13.3
New+replace purchase costs	billion EUR (10^9)	48	38	37	29	23	19	15
Glazing replace./maint. costs	billion EUR (10^9)	32	28	27	24	21	19	18
Energy costs	billion EUR (10^9)	86	66	46	26	15	11	9
Overall costs	billion EUR (10^9)	166	132	110	79	60	49	42
Employees	'000			280	280	279	283	290
Avg. heating perf. new	kWh/m2*yr	114	77	30	18	15	11	8
Avg. cooling perf. new	kWh/m2*yr	67	63	57	53	52	50	48
Stock cool.perf.	TWh_cool	246	256	261	255	247	239	232
Share window heat loss of heat demand	%	37%	31%	24%	15%	10%	7%	6%

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The table below presents the annual sales, stock and impacts / related energy consumption (accordance with MEERP 2011 requirements) for the BAU scenario / non-residential sector.

Table 16 BAU Scenario / non-residential

OUTPUT Non-residential		1990	2000	2010	2020	2030	2040	2050
Sales new build	'10^6 m2/yr	14	15	19	18	18	17	17
Demolished	'10^6 m2/yr	-5	-5	-5	-6	-8	-10	-12
Sales replacements	'10^6 m2/yr	21	24	27	30	32	34	35
Total stock	'10^9 m2/yr	0.8	0.9	1.1	1.2	1.3	1.4	1.4
Heating energy	TWh_fuel	130	108	80	50	30	21.2	17.1
Cooling energy	TWh_fuel	48	68	62	49	42	37.6	33.9
Final energy windows	TWh_fuel/yr	178	175	142	99	72	59	51
	PJ_prim	642	631	511	355	258	212	184
GHG Emissions	Mt CO2 eq./yr	37	36	28	19	14	11	9
Mat. in	kt	720	837	1059	1149	1220	1278	1318
Mat. out	kt	-505	-597	-713	-842	-967	-1073	-1171
Indirect energy	TWh_fuel	5	7	9.5	9.0	7.6	6.1	5.2
New+replace purchase costs	billion EUR (10^9)	11	11	11	9	7	6	5
Glazing replace./maintenance costs	billion EUR (10^9)	8	7	7	6	6	6	5
Energy costs	billion EUR (10^9)	10	11	9	7	5	5	4
Overall costs	billion EUR (10^9)	29	29	28	22	19	16	14
Employees	'000			146	134	127	123	122
Avg. heating perf. new	kWh/m2*yr	51	39	23	18	16	14	12
Avg. cooling perf. new	kWh/m2*yr	75	71	65	60	58	56	54
Stock cool.perf.	TWh_cool	65	71	77	79	82	82	82
Share window heat loss of heat demand	%	5%	5%	4%	3%	3%	2%	3%

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The table below presents the annual sales, stock and impacts / related energy consumption (accordance with MEERP 2011 requirements) for the BAU scenario / roof window sector.

Table 17 BAU Scenario / roof windows

OUTPUT		1990	2000	2010	2020	2030	2040	2050
Sales new build	'10^6 m2/yr	5	4	5	5	5	5	4
Demolished	'10^6 m2/yr	-1	-1	-2	-2	-3	-3	-4
Sales replacements	'10^6 m2/yr	7	8	8	9	10	10	10
Total stock	'10^9 m2/yr	0.3	0.3	0.3	0.4	0.4	0.4	0.4
Heating energy	TWh_fuel	97	75	54	30	15	9.2	6.6
Cooling energy	TWh_fuel	6	10	14	13	12	11.6	11.0
Final energy windows	TWh_fuel/yr	103	85	68	42	27	21	18
	PJ_prim	369	307	246	152	99	75	63
GHG Emissions	Mt CO2 eq./yr	21	17	13.0	8.0	5.2	3.9	3.1
Mat. in	kt	400	403	461	491	504	513	516
Mat. out	kt	-238	-284	-328	-377	-427	-457	-487
Indirect energy	TWh_fuel	2	2	2.3	2.2	2.0	1.8	1.6
New+replace purchase costs	billion EUR (10^9)	6	5	5.7	5.4	4.7	4.0	3.5
Glazing replace./maintenance costs	billion EUR (10^9)	3	2	2.2	2.0	1.8	1.7	1.6
Energy costs	billion EUR (10^9)	7	7	6.1	4.2	3.2	2.7	2.4
Overall costs	billion EUR (10^9)	16	14	14.0	11.7	9.7	8.4	7.5
Employees	'000			113	97	85	76	70
Avg. heating perf. new	kWh/m2*yr	105	83	48	18	18	18	18
Avg. cooling perf. new	kWh/m2*yr	146	141	124	110	110	110	110
Stock cool.perf.	TWh_cool	41	45	47	47	47	46	46
Share window heat loss of heat demand	%	26%	22%	19%	12%	9%	7%	6%

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Basic model assumptions and other variables are further explained in TASK 7 as this TASK's Business-as-usual scenario is identical to the above presented values.

4.6.2. STOCK BUILD-UP FOR RESIDENTIAL, NON-RESIDENTIAL AND ROOF WINDOWS

Figure 5 Stock build-up by age façade windows (residential sector)

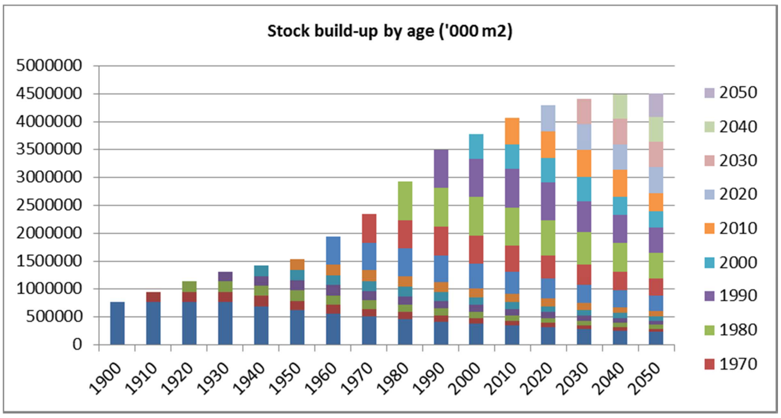


Figure 6 Stock build-up by age façade windows (non-residential sector)

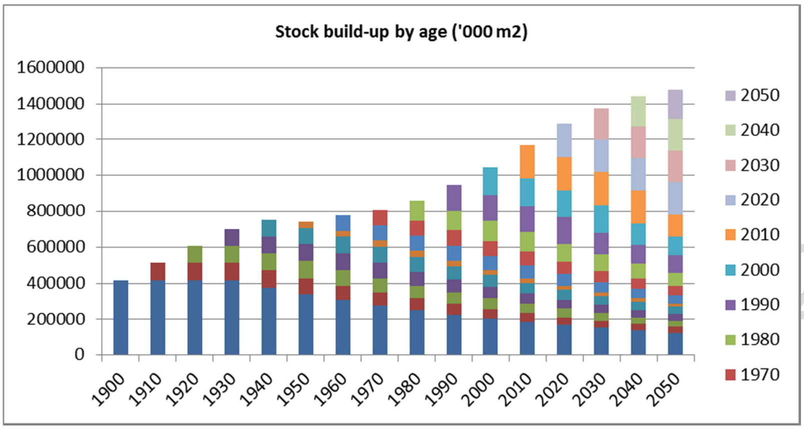
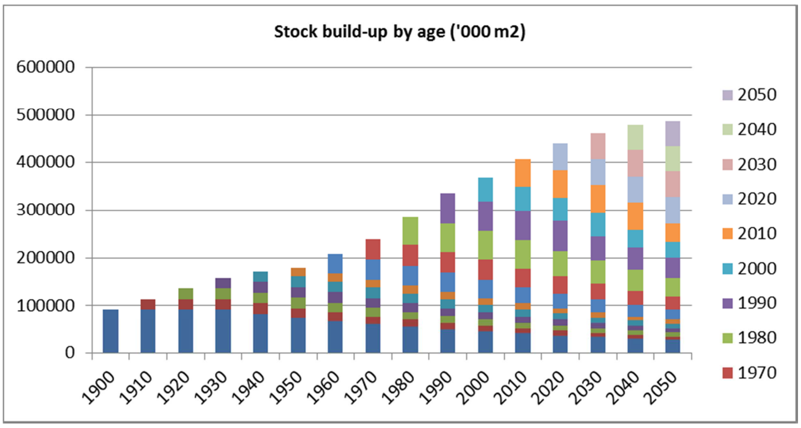


Figure 7 Stock build-up by age roof windows



CHAPTER 5 END-OF-LIFE ASPECTS

According the MEErP methodology this section is to identify, retrieve and analyse data, report on consumer behaviour (avg. EU) regarding end-of-life aspects. This includes:

- Product use & stock life (=time between purchase and disposal);
- Repair- and maintenance practice (frequency, spare parts, transportation and other impact parameters);
- Collection rates, by fraction (consumer perspective);
- Estimated second hand use, fraction of total and estimated second product life (in practice);
- Best Practice in sustainable product use, amongst others regarding the items above.

5.1. End-of-life aspects

5.1.1. Product use & stock life

For the window frame, a product life of 25-50 years appears acceptable by most stakeholders. If a relative long product life is selected as reference, e.g. > 40 years, it is assumed that the glazing unit is replaced at least once. If a shorter product life, e.g. ≤ 30 years, it is accepted that the glazing unit is not replaced.

It should be noted that the actual window properties, the installation characteristics and actual position (facing south, north, east or west, sloped or vertical, close to sea or not, etc.) and the maintenance have a very large effect on product life of the window and its components.

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5.1.2. Repair & maintenance

The various window systems placed on the market may impose very different demands on the type and level of maintenance required. Certain window systems (mainly determined by frame material) are claimed to be virtually maintenance free, whereas others require regular inspection and coating (painting). Windows, including its hinges, closing mechanisms, etc. require repair if maintenance has been neglected or the unit is not used properly. The user therefore has a large influence on the total amount of maintenance required and the longevity of the window product, which is particularly true for wooden windows. Failure of hardware may be impacting the product life of plastic and metal window frames more than for wooden windows.

5.1.3. Collection rates and Second-hand use

Re-use or material recovery and collection rates are covered in the "end-of-life" section in Task 4, section 4.5. Second-hand use of windows is negligible.

5.1.4. Best practice in sustainable product use

Best practice in sustainable product use very much depends on the characteristics of the window and the building (space) it is used in. Building space requirements determine to a large degree the optimum use of windows (what indoor temperature or light level is acceptable, etc.). Two aspects that requires thorough attention are the use of adaptable elements of the window for changing the thermal and radiation properties (such as internal, external or integrated window covering) and the use of ventilation options (openable windows).

In periods of heating demand the window should ideally (glare, privacy and other personal preferences permitting) allow the maximum solar gains to pass through the window. In periods of low or no solar irradiance (cloud cover, nights) adaptable elements (if any, such as window covering) can be used to improve the thermal resistance. In periods where there is no heat demand, the solar gains should be reduced in order to avoid overheating (use of adaptable elements, such as window covering, to reduce/block irradiance). Ventilation options (openable windows) may be used to remove excess heat, especially in periods when the outdoor temperature is lower than the indoor temperature (night time ventilation, free cooling).

CHAPTER 6 LOCAL INFRA-STRUCTURE

According the MEErP methodology this section is to identify, retrieve and analyse data, report on barriers and opportunities relating to the local infra-structure regarding:

- Energy: reliability, availability and nature
- Water (e.g. use of rain water, possibilities for "hot fill" dishwashers);
- Telecom (e.g. hot spots, WLAN, etc.);
- Installation, e.g. availability and level of know-how/training of installers;
- Physical environment, e.g. fraction of shared products, possibilities for shared laundry rooms, etc.

As energy (reliability, availability, nature), water and telecom are not relevant for this energy-related product, this section will only deal with installation issues and other aspects relevant for barriers and opportunities regarding the local infrastructure.

6.1. Barriers

The following barriers relating to the local infrastructure have been identified:

- 'holistic approach' needed in case of window replacement (consider other building components / installations; air tightness, etc.);
- existing frames will not accept improved IGU's (much less so for roof windows as sizes are more standardised);
- an improvement of the window may affect energy systems differently (e.g.: lower g-value has positive effect on cooling energy, negative on heating or lighting energy);

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Not related to the local infrastructure but nonetheless a barrier is the so-called 'split incentive', in which investment costs and recuperation of these costs are borne by different parties (owner, renter). This occurs almost by default in all rented buildings.

6.2. Opportunities

As opportunity for window improvement, relating to the local infrastructure, is identified the replacement of the IGU or of the complete window. This may occur in situations typically described as new builds, 'deep' renovation or 'shallow' replacement/renovation.

It is possible to purchase shading devises (external and internal) that fit the standard sizes of roof windows. The possibility of adding a shading device to existing windows can improve the energy performance. Likewise adding an IGU with solar protected glazing or adding automation for ventilative cooling may improve overall window performance or reduce impacts on affected energy systems.

CHAPTER 7 RECOMMENDATIONS

According the MEErP methodology this Chapter is to make recommendations on:

- refined product scope from the perspective of consumer behaviour and infrastructure
- barriers and opportunities for Ecodesign from the perspective of consumer behaviour and infrastructure.

7.1. REFINED SCOPE

The TASK 3 User analysis did not result in further information that requires a revision or fine-tuning of the study scope from the perspective of consumer behaviour and infrastructure.

The exclusion of certain types of windows from scope as defined in TASK 1 continues to apply.

7.2. BARRIERS AND OPPORTUNITIES

Barriers and opportunities for Ecodesign from the perspective of consumer behaviour and infrastructure have been dealt with in TASK 1.

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ANNEX I – CALCULATION OF WINDOW IMPACT ON RELATED ENERGY SYSTEMS

This section presents the equations used to calculate the heating and cooling performance of windows, using ABC/XYZ values as defined in the main text.

The related TASK 7 (more specifically Annex I and Annex II) describe in more detail the definition of the ABC/XYZ values.

Energy performance index for heating

The window energy performance index for heating $P_{E,H,W}$ has been determined according to the following energy balance equation.

$$P_{E,H,W} = A \cdot (U_{W,eff} + H_{ve,w}) - B \cdot g_W \qquad (1)$$

The first term characterises the heat losses due to thermal transmittance and infiltration. The second term characterises the heat gains due to solar radiation. If the second term is larger than the first the energy performance index gets negative. This is the case if the solar energy gains of a window are higher than the energy losses. Than the window is a net energy gaining building element. The energy gain can be used to compensate energy losses of other building elements e.g. wall, roof.

The effective thermal transmittance of the window is calculated according to:

$$U_{W,eff} = (1 - C) \cdot U_W + C \cdot U_{W,S}$$

$$U_{W,S} = (1/U_W + \Delta R)^{-1}$$

The equation takes into account the reduction of the thermal transmittance of the window with a closed shutter.

The transmittance caused by infiltration is calculated according to

$$H_{ve,w} = \left(\frac{\Delta p}{100 Pa}\right)^{2/3} \rho \cdot c_p \cdot Q_{100}$$

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The solar energy transmittance of the window g_W is calculated according to

$$g_W = g \cdot (1 - F_F)$$

The necessary characteristics of the window, given in Table 1, are determined according to harmonized European standards. This information is in general already available for the window manufacturer. Therefore there is no additional burden as far as the determination of the relevant characteristics is concerned.

The Parameters A,B,C are in general derived by an hourly calculation method

Table 18 Necessary Parameters necessary for the calculation of the energy performance index for heating

Symbol	Description	Unit	Source
A	Heating degree hours	kKh	Derived from hourly calculation
B	"Useable" solar radiation	kWh/m^2	Derived from hourly calculation
C	dimensionless fraction of accumulated temperature difference for period with shutter closed	-	Derived from hourly calculation

Energy performance index for cooling

The window energy performance index for cooling $P_{E,C,W}$ can be determined according to the following energy balance equation.

$$P_{E,C,W} = -X \cdot (U_W + H_{ve,w}) + Y \cdot g_{W,eff}$$

with

$$H_{ve,w} = \left(\frac{\Delta p}{100Pa}\right)^{2/3} \rho \cdot c_p \cdot Q_{100}$$

$$g_{W,eff} = (1 - F_F) \cdot \left[(1 - Z) \cdot g + Z \cdot g_t\right]$$

The necessary characteristics of the window to calculate the energy performance index for cooling, given in Table 2, are determined according to harmonized European standards. This information is in general already available for the window manufacturer. Therefore there is no additional burden as far as the determination of the relevant characteristics is concerned.

Table 19 Necessary parameters for the calculation of the energy performance index for cooling

Symbol	Description	Unit	Source
X	Cooling degree hours	kKh	Derived from hourly calculation
Y	Solar radiation that leads to overheating	kWh/m^2	Derived from hourly calculation
Z	dimensionless weighted fraction for period with shutter closed	-	Derived from hourly calculation

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