

“Towards improved quality of the works”
**Documented examples of existing situations
regarding quality of works**



Final report, March 2016

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Executive summary

This report, written in the context of the IEE project QUALICHeCK, summarises critical situations on the construction site that are liable to put the careful execution and thus the high quality of works at risk. It gives an introduction into the importance of high quality constructions and their realisation on the building site in connection with the trend towards high performance buildings such as the nearly zero-energy buildings required by the Energy Performance of Buildings Directive (Recast) for 2019 respectively 2021.

First, a matrix of possible critical situations encountered on the construction site was developed, ranging from general issues like missing specifications, insufficient knowledge and training of the workers, etc. to more specific problems with certain building envelope components and material and to building service systems and their components. The critical situations are opposed to four technology focus areas in the QUALICHeCK project (transmission characteristics, ventilation and air tightness, sustainable summer comfort technologies, and renewables in multi-energy systems). Reasons for problems with the quality of works have been structured and comprise poor specifications of projects, standards or regulations, lack of competences, critical economic conditions and lack of control.

All in all, 28 studies and other documented experiences that show the probability, the reasons and the impact of incorrect realisation processes at the building sites have been collected in the participating countries of the project and are inserted into the matrix. They are also included in a tabular overview and presented in greater detail, including references. For several countries the results of the BUILD UP Skills projects, that analysed the need for competent workforce, could be included. Several documented studies deal with specific technologies such as heat pumps, solar thermal systems, PV systems, ventilation systems or insulation material and technologies such as loose fill material or external thermal insulation composite systems (ETICS). Other studies are based on building inspections to guarantee a high quality of works and give an overall impression of mistakes occurring on construction sites. Based on the gathered documented experiences there seems to be considerable knowledge of the situation in some of the focus areas like building envelope airtightness and ductwork airtightness (especially in Northern and Middle European countries), but less knowledge of issues like sustainable summer comfort and renewables in multi-energy systems.

Additionally, a first collection of best practice solutions to avoid low quality realisations is presented in the report. They will build the basis for further work in the project. So far, the collection includes several guidelines for improving the quality of works, some training and certification schemes for installers and other workers that are partly driven by the industry involved and some control schemes realised by experts from third parties. The control schemes are mostly voluntary. If they are associated with financial schemes they often present a mandatory check for receiving the financial support.

This document is the final public version of a draft report published in March 2013 that was intended for discussion with stakeholders, both bilaterally and during workshops. This earlier collection of studies and experiences has been extended based on further work within the project and feedback from stakeholders.

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I. Introduction

Compared to today's practice, the trend towards Nearly Zero-Energy Buildings (NZEB) implies:

- ✓ The correct execution of classical building works, in line with the NZEB principles of good workmanship (e.g., airtightness, correct execution of building nodes, etc.).
- ✓ The use of advanced technologies requiring specific skills of the workforce (e.g., use of RES in combined HVAC systems, advanced ventilation systems).

Therefore, to reach NZEB targets in practice, this observation calls to explore means to improve the quality of the works, which implies:

- ✓ To agree what is understood by 'good' quality of the works (indicators, performance levels, etc.).
- ✓ To guarantee the existence in the market of good products, as well as the existence of all required competences among designers and executors to deliver a good job.
- ✓ To define and guarantee boundary conditions allowing the various players to deliver the agreed quality level in economically viable conditions.

QUALICHeCK is focusing on establishing good technical boundary conditions for quality of the works. It is thereby important to understand that technical requirements are a prerequisite for having a framework that allows compliance and effective penalties related to the quality of the works. In particular, it is crucial that there is no confusion in the market about the procedure(s) to be followed for showing the quality of the works, otherwise there is no solid basis for an effective sanctioning approach. On the other hand, the insights from these technical requirements are important boundary conditions for establishing an effective compliance and sanctioning framework.

The ultimate goal is to stimulate the development of schemes to improve the quality of the works, taking into account the pros and cons of previous experience, with specific attention given to boundary conditions and allowing effective compliance. The work will document and build on successful initiatives to overcome site implementation issues that undermine the confidence in actual performance.

These initiatives include examples in the context of regulatory frameworks, quality labels, self-control or quality management procedures/guidelines, and training programmes.

This QUALICHeCK report presents a series of critical situations on the construction site that can result in poor quality of works and thus in poor energy performance of the building or its service systems focusing on transmission characteristics, ventilation, sustainable summer comfort technologies and renewables in multi-energy systems. Examples of national and international experiences and studies illustrate certain critical situations and allow an estimation of their impact. The report is based on an earlier draft version available since March 2013 and has been extended with information from further experiences and feedback from stakeholders.

II. Collection of examples of critical situations on the construction site regarding the quality of works

The following matrix shows examples of possible critical situations that can happen during the construction of new buildings and major renovations of existing building; it also indicates at which focus area they will have an impact. Fields with **white** letters refer to specific studies on the critical situations; fields with **black** letters refer to best practice approaches to solve the situations.

QUALICheck focus area			Transmission characteristics		Ventilation			Sustainable summer comfort technologies	Renewables in multi-energy systems
			Whole component	Thermal bridges	Airtightness of envelope	Airtightness of ducts	Systems		
Critical situation									
Very general	No or poor specifications of product performances		D1	D1				D1	
	No or poor specifications of execution performances						A2		
	No framework for control of performances								
	Time pressure		S1, S4	S1, S4	S1, S4	S4	S4	S4	S4
	Language barriers at construction sites			BI					
	Insufficient knowledge of new technologies/construction workers not adequately trained		C1 / E1 / R1 / S1 / S4 / AIII / CI	C1 / E1 / R1 / S1 / S4 / AIII / CI	C1 / E1 / R1 / S1 / S4 / S5 / AII / AIII / CI	E1 / S4	E1 / R1 / S4 / AI / AII	C1 / E1 / S4 / CI	C1 / E1 / R1 / S4 / AI / AII / CI
	Necessary specialists not part of the construction team		C1 / R1 / S4 / AIII / CI	C1 / R1 / S4 / AIII / CI	C1 / R1 / S4 / S5 / AIII / CI	S4	R1 / S4 / AI / AII	C1 / S4 / CI	C1 / R1 / S4 / AI / AII / CI
	Poor communication between planners and contractors		S4 / SIII	S4 / SIII	S4 / S5 / SIII	S4 / SIII	S4 / SIII	S4 / SIII	S4 / SIII
	Lack of technical details (improvisation on construction site)		S4 / EI	S4 / BI / EI	S4 / S5 / EI	S4 / EI	S4 / EI	S4 / EI	EU2 / S4 / EI
	Constructed building components/ technologies not documented as a basis for subsequent maintenance						UK1	AI	EU2 / F7 / AI
Building envelope Opaque General	Wrong (insulation) material: λ -value, thickness, etc.		D1 / E2 / S2 / CI / RI					D1 / CI	
	Incomplete or incorrectly installed insulation layer: gaps, uneven surfaces		B3 / S1 / C1 / EI / RI / UKI / UKII	B3 / S1 / CI / EI / RI / UKI / UKII				EI	
	Incompatible (insulation) material to specific situations: e.g. vacuum insulation		RI						
	Damages of insulation material during construction		E2 / S1 / RI	RI					
	Wet (insulation) material: storage on site, protection during construction		E2 / S1 / RI						
	Incorrect waterproof layers in wet areas (bathrooms, etc.)		E2 / S1 / RI / SI	RI					
	Not enough drying time for built-in moisture (concrete, wood)		E2 / RI						
	Wrong airtightness material				B2 / EI / RI				
	Incomplete air or moisture barrier		E2 / RI	RI	RI	RI			
	Damages of air or moisture barrier during the implementation		E2 / RI	RI	RI				

QUALICHeCK focus area			Transmission characteristics		Ventilation			Sustainable summer comfort technologies	Renewables in multi-energy systems
			Whole component	Thermal bridges	Airtightness of envelope	Airtightness of ducts	Systems		
Critical situation									
Building envelope (cont.)	Opaque	General (cont.)	Joints not realised with insulation according to requirements/design		B3 / D1 / BI / RI				
			Joints not watertight/airtight	E2 / S3 / RI	RI	E2 / B2 / RI			
			Incorrectly realised joints due to installations (pipes, ducts)						
		Components to ground	Wrong (insulation) material: water resistance	E2 / S1 / RI					
		Base slab/ foundations	Wrong (insulation) material: pressure resistance	E2 / RI					
		Ventilated roof	Not enough air space for ventilated roof						
			Not enough openings for ventilated roof						
		Cool roof	Wrong coating for cool roof					US-GI	
	Transparent	General	Wrong windows or façade elements: U-value	D1 / RI				D1	
			Wrong windows or façade elements: g-value, τ -value	D1 / RI				D1	
			Joints between windows and walls not insulated		D1 / E2 / BI / DI / DII / EI / RI				
			Joints between windows and walls not watertight/airtight	D1 / E2 / S1 / RI	D1 / S1 / DI / DII / EI / RI	D1 / S1 / EI / RI			
		Shading systems	Top mounted roller shutters uninsulated at contact surface to wall		D1				
			Blinds without sufficient rear-ventilation						
Building service systems	General		Wrong system components installed: collector peak load, inverter efficiency, fan efficiency, pump efficiency, etc.						F4
			Incorrect setting of hydraulic flows						A1 / F3 / S1 / EU2
			No hydraulic calibration						
	Fixation		Incompatible mounting material: anchors, etc.						
	Pipes/ducts		Wrong diameters of pipes/ducts						F3
			No/poor insulation of pipes/ducts						F3 / F7 / FI
			No accessibility for cleaning						
			Duct connections not airtight			EU1 / EU3 / NL1 / UK1 / SII			
			Joints with other system components not airtight: fan, AHU			EU1 / EU3 / UK1 / SII			
	Control		Wrong settings: night setback, CO ₂ /humidity/temperature controls				UK1		A1 / EU2 / FI

QUALICheck focus area			Transmission characteristics		Ventilation			Sustainable summer comfort technologies	Renewables in multi-energy systems
			Whole component	Thermal bridges	Airtightness of envelope	Airtightness of ducts	Systems		
Critical situation									
Building service systems (cont.)	Technologies (cont.)	PV system	Damaged PV cells						
			Not enough rear ventilation						
			Cables: no mechanical protection						F5
			Cables: Mistakes regarding parallel vs. series connection						
			No connection to inverter						
			Insulation behind the arrays not high temperature resistant						
			Incorrect installation on the roof, causing water leakage						
			Incorrect installation on the roof, causing damages on the roof/PV cells after storms						B1
		Solar thermal	Not enough distance/insulation behind collectors at walls/roofs						
			Insulation behind the panels not high temperature resistant (e.g. integrated in facades)						
			Storage feed-in at middle/top						EU2
			Wrong type of antifreeze liquid						F4
			Safety valve not fitted to container/ container not empty						F4
		Heat pump	Setting: no priority for DHW						FI
			Storage feed-in at top (DHW) and middle (heating)						FI
			Too low refrigerant quantity						F1 / FI
			Incorrect positioning of the outdoor unit (too close to walls, in an attic) -> poor performance						F1 / FI
			Time for defrosting of the outdoor heat exchanger set at a too low value -> poor performance						F1 / FI
		Wood boiler	Incorrect flue gas exhaust at boiler						F6
			Incorrect ventilation openings in boiler room						F6
		Ventilation system	Setting of airflow rate on default instead of specific necessary setting/wrong air flow rates						
			Required filters not included				A2		
			No electrical connection of the auxiliary heating				F1		
			Installation without accessibility for maintenance				A2		
			Noise: ventilation unit in wrong position				NL1		
			Noise: silencers not properly installed				NL1		

The critical situations are further explained in the Annex.

III. Synthesis of types of reasons for problems with quality of works

As illustrated by the 70 listed examples of potential quality problems, there can be a wide range of reasons for poor quality:

1. Poor specifications at level of projects, standards and/or regulations:
 - a. with respect to materials to be used (e.g. with respect to material characteristics of insulation, correct construction details (joints), ...);
 - b. with respect to the performances to be achieved (e.g. air- and water-tightness, wind resistance for PV panels, acoustical performances of ventilation systems, ...);
 - c. with respect to the execution principle (e.g. under which conditions may roofing be installed).
2. Lack of competence
 - a. at designer level (see also QUALICHeCK work package “Reliable and easily accessible input data”);
 - b. at execution level;
 - c. language barriers.
3. Critical economic conditions
 - a. critical financial conditions;
 - b. critical timing conditions.
4. Lack of control
 - a. by parties involved in the project;
 - b. by third parties (government, independent control organisations, ...).

In order to achieve good quality of the works, it is important to analyse the (primary) reasons for poor quality and identify possibilities for improving the boundary conditions. It is fundamental to understand that the boundary conditions may vary substantially between countries, between technologies, between types of projects. Experience shows that it is usually difficult to change these boundary conditions because it may imply to revisit standard practice of product and building design, etc. Therefore, one should try to find approaches which are supported by the key stakeholders involved.

IV. Quality of the works – the viewpoint of compliance control and enforcement

In terms of compliance, quality of the works is important with regard to the contract specifications, with regard to voluntary quality assurance frameworks specifying the rules to be followed, and possibly also with regard to the EPC.

It depends on the rules for determining EPC input data whether quality of the works has an implication on the EPC or not. If the preliminary EPC issued at building permit stage has to be updated with as-built data, quality of the works will have a major impact on compliance. However, in many countries quality of the works does not affect the EPC yet, because input data are derived from design documents and checks are carried out at the level of energy performance minimum requirements. A few countries have introduced EPC control addressing the as-built situation, e.g. by requiring air-tightness measurements.

Experience with voluntary quality frameworks shows that quality of the works in general (with regard to the specifications), and quality of the works relevant for the as-built energy performance is lacking behind. However, mistakes are not always detected. Especially in the field of nearly zero energy buildings tasks are more demanding, and a higher level of skills is required: this affects the work force but also the site supervisors or other staff occupied with checking the quality of the works.

Vocational training programmes and certifications are important elements of improving the quality of the works. Control is another important element, because experience shows that quality will improve, simply as a consequence of carrying out random checks. The previous chapter states that project investigations resulted in the conclusion that there is a lack of control at the moment, which does not help promoting the quality of the works.

Checking and enforcing compliance requires human and financial resources and must therefore focus on the most crucial aspects. This report investigates quality of the works aspects influencing the actual energy consumption of buildings, paying specific attention to nearly zero energy buildings. It presents a comprehensive analysis, including general reasons such as time pressure and language problems. These general problems have to be solved by market actors are not dealt with further in the project. However, the identified problems related with the building envelope, building services systems, and renewable energy systems can be used for the development of checklists to be applied in the course of control procedures.

In terms of enforcement, financial penalties are probably problematic, because we are interested in an actual high performance building, and it should not be an option to deliver bad quality of the works and balance it with a fine. Severe financial penalties, which could be effective, might most probably lack societal support. Therefore, trade-specific controls at crucial stages during construction with the obligation to correct mistakes, might be most effective in the long run. However, this is a resource-intensive procedure, irrespectively whether control is carried out by government or a third party.

V. Experiences/studies of critical situations regarding the quality of works

Based on the overview of possible reasons for poor quality of works two sets of examples have been collected:

- ✓ On the one hand a description of 28 experience reports/studies of critical situations. A brief description is given in table 1 prior to a more detailed text description per situation.
- ✓ On the other hand 18 best practice examples to solve critical situations, see next chapter. These examples are summarised in table 4 and described more comprehensively thereafter.

Study	Country	Reported by	Covered areas	Date of study	Trans-ferability	Results/ consequences
Field test on combined heat pump and solar thermal systems	Austria	OEGNB	Heat pumps, solar thermal systems	2010-2013	National, international	Revised training material for installers
Study on ventilation systems in classrooms	Austria	OEGNB	Mechanical ventilation systems in classrooms	2008	National, international	Revised training material for ventilation installers
Impact of storm on PV systems	Belgium	BBRI	Installation of PV systems	2010-2013	National, international	Development of design and installation specifications
Study on building airtightness	Belgium	BBRI	Airtightness	2014	National, international	Systematic measurements may be required for NZEBs
Quality of installation of thermal insulation in cavity walls	Belgium	Ghent University	Insulation material, uneven surfaces, joints	1990-2014	National, international	Improved training of masons, change in construction sequence and product development
Cypriot analysis of the National Status Quo within BUILD UP Skills	Cyprus	The Cyprus Institute	Insufficient knowledge/training, necessary specialists not part of construction team	2012	National, international	Roadmap for policies and actions for construction sector employees
Burgholzshof study	Germany	Fraunhofer IBP	Insulation material, quality of windows, thermal bridges, window seams, roller shutters	2002	National, international	General: revision of U-value definitions; practical recommendations

Table 1: Overview on collected experiences with or studies of critical situations regarding the quality on the construction site.

Study	Country	Reported by	Covered areas	Date of study	Trans-ferability	Results/ consequences
Estonian analysis of the National Status Quo within Build Up Skills	Estonia	Tallinn University of Technology	Insufficient knowledge of new technologies/construction workers not adequately trained	2012	National	The number of skilled work-force needs to be increased
Estonian housing stock technical condition - apartment buildings (1990-2010)	Estonia	Tallinn University of Technology	Insulation material, damages on construction site, wet insulation, waterproof layers, built-in moisture, moisture and air barriers, joints	2010-2012	National, countries with similar constructions & climate, partly international	Guidelines for designers and builders
Quality of ventilation systems in residential buildings: status and perspectives in Estonia	Estonia	Tallinn University of Technology	Ventilation systems: Joints not airtight, no accessibility for cleaning/maintenance, wrong settings, filters not included	2013	National, partly international	Guidelines for HVAC designers and builders
EU project SAVE DUCT	EU (focus on Belgium, France, Sweden)	BBRI	Ductwork, airtightness	1997-1998	International	Recommendations to use circular ducts and factory-fitted sealing gaskets
EU project CombiSol	EU (focus on Austria, France, Germany, Sweden)	OEGNB	Installation of solar thermal systems	2007-2010	International. Test included systems from 4 countries	Guidelines for manufacturers and installers
Duct leakage in air distribution systems	EU	Tallinn University of Technology	Airtightness of ventilation ducts	1999	International	Calculation of energy saving potential
Study on common problems with heat pumps	France	Cetiat	Heat pumps	2009	National only	Advice to join the quality label QualiPac
Quality of ventilation systems in new dwellings	France	CETIAT	Installation and commissioning of ventilation systems	2013 - 2016	National	The French Effinergie+ label plans to reinforce ventilation controls

Table 1 (cont.): Overview on collected experiences with or studies of critical situations regarding the quality on the construction site.

Study	Country	Reported by	Covered areas	Date of study	Trans-ferability	Results/ consequences
Quality of large solar thermal domestic hot water systems	France	CETIAT	Solar thermal domestic hot water systems	2013	National	Proposal for increased training, quality checks, systematic commissioning, measurements
Quality of solar thermal domestic hot water systems in houses	France	CETIAT	Solar thermal domestic hot water systems	2007 - 2012	National	Check-up files for installers, help line for technical advice, journal with good practice
Quality of photovoltaic installations	France	CETIAT	Photovoltaic systems	2012	National	Check-up files for installers, help line for technical advice, journal with good practice
Quality of domestic wood boiler installations	France	CETIAT	Wood boilers	2012	National	Check-up files for installers, help line for technical advice, journal with good practice
Quality of heat pump installations	France	CETIAT	Wood boilers	2012	National	Check-up files for installers, help line for technical advice, journal with good practice
Performance and quality of mechanical ventilation systems in dwellings	The Netherlands	Tallinn University of Technology	Ventilation systems	2012	National	Process-related recommendations for better performance
Romanian analysis of the National Status Quo within Build Up Skills	Romania	URBAN-INCERC	Time pressure, insufficient knowledge/training, necessary specialists not part of the construction team	2012	National	Starting point for the definition of a national qualification strategy and a roadmap

Table 1 (cont.): Overview on collected experiences with or studies of critical situations regarding the quality on the construction site.

Study	Country	Reported by	Covered areas	Date of study	Trans-ferability	Results/ consequences
Småhus-kadenämnden (The board for moisture and mould damages in single-family house)	Sweden	Chalmers University of Technology	Time pressure, insufficient know-ledge/training, in-sulation material, construction dama-ges, wet material, waterproof layer, water resistance, hydraulic flows	2001	National, countries with simi-lar con-structions & climate, partly internation-al	Education and information reg. less risky con-struction types. Foundations with insulation above concrete slabs are no longer used.
Wrong insula-tion material in loose fill insulations in attics	Sweden	Chalmers University of Technology	Wrong insulation material; λ -value, thickness, etc.	1998	Internatio-nal	Practical recom-mendations for improvement
Problems with external ther-mal insulation composite systems (ETICS)	Sweden	Chalmers University of Technology	Joints not watertight/airtight	2009	National, countries with simi-lar con-structions & climate	Recommenda-tions for safe ETICS constructions in the Swedish situation
The causes and costs of defects in construction	Sweden	Chalmers University of Technology	General, especially lack of motivation/ control	1999	Probably interna-tional	45 % of the detected defects originated from the construction site, mostly by lack of motivation
Factors that affect the building's air tightness	Sweden	Chalmers University of Technology	Building airtightness	2010	National, countries with simi-lar con-structions	Recommenda-tions for im-proved building airtightness (0.3 l/sm ²)
Quality of ventilation systems	United Kingdom of Great Britain	Tallinn University of Technology	Ventilation systems	2011	National	Freely available flow measure-ment guide

Table 1 (cont.): Overview on collected experiences with or studies of critical situations regarding the quality on the construction site.

A1 *Austrian field test on combined heat pump and solar thermal systems: SolPumpEff*

Reported by: Susanne Geissler, OEGNB

Responsible authors of the field test: AEE INTEC, Technische Universität Graz, Solution - Greiner Renewable Energy, Ochsner Wärmepumpen AG

Covered areas: Installation of heat pumps and solar thermal systems

Date of study: 2010-2013

Summary: In the scope of this project (funded by the Austrian Climate and Energy Fund) a field test and monitoring of solar thermal systems combined with heat pumps were carried out. The conclusions were:

- ✓ Heat pumps are sensitive to absolutely minor planning and installation mistakes and bad adjustment of control.
- ✓ Optimisation included correct positioning of sensors, improved control settings, and hydraulic flows.
- ✓ Quality assurance is a high priority task to be administered by the legislative body and the funding organisation.

Transferability of experiences to other construction sites/other countries: National, International

Results/consequences of the study: Among others, the study resulted in contributions to revising the training material for the certified heat pump installer course and the certified solar thermal installer course.

References: [40]

A2 *Austrian study on ventilation systems in classrooms*

Reported by: Susanne Geissler, OEGNB

Responsible authors of the study: FHS Kufstein Tirol, AEE INTEC, ENERGIE TIROL, arsenal research, Interuniversitäres Forschungszentrum, Donauuniversität Krems

Covered areas: Installation of ventilation systems

Date of study: 2008

Summary: The study was funded by the Austrian Federal Ministry of Transport, Innovation and Technology within the programme “Building of Tomorrow”. The technical evaluation of the ventilation systems focused on the following aspects: the choice of ventilation concept (decentralised, semi-central, central), air mass and air distribution, the loss of pressure, the type of heat recovery, the electrical energy need, the type of anti-freezing protection, the type of reheating to comfort temperature, the indoor air quality achieved (carbon dioxide, humidity, VOC), necessary repairs and maintenance costs as well as the current noise load.

The conclusions were that there are many shortcomings due to mistakes made during planning and installation including:

- ✓ poor specifications of execution performances in the tender;
- ✓ reduced ventilation rates due to noise problems;
- ✓ filter change problems;
- ✓ partly incorrect filters installed.

Transferability of experiences to other construction sites/other countries: National, international

Results/consequences of the study: As a result of the study, a planning guideline and 61 detailed quality criteria for classroom ventilation systems were developed, based on the results of existing planning directives, drafts of standards and standards as well as the results of the analysis of acceptance and the technical evaluation. In addition, the study resulted in contributions to revising the training material for the ventilation installer course.

References: [13]

B1 *Belgian study on PV mounting*

Reported by: Eric Dupont, Belgian Building Research Centre (BBRI)

Covered areas: Storm damages on photovoltaic installations, reasons and remedies

Date of study: 2011-2013

Summary: In the period 2006-2012 the market uptake of photovoltaic has been stimulated by the possibility of tax deductions. Many new companies have been set up and also existing companies became active as installers of PV installations. There was not in all cases sufficient expertise in the roof techniques and structural design issues. One of the main consequences of this situation is that the wind resistance of many installations appears to be insufficient. Most frequently, the applied ballast seems to be too limited. Movement joints, wind bracings, fixations of the ballast on the structure are also often neglected.

A storm which happened on the 3rd January 2003 has resulted in major damages. In spite of the fact that it was not an extreme storm (wind return period of 3 to 4 years, wind gust velocity about 100 km/h), an assurance company reported to BBRI that more than 100 installations, mainly on flat roofs, had been severely damaged. 70 installers were affected, involving a total bill of 700,000 €.

Consequently, practical guidelines for wind resistance had to be improved. Within that context, BBRI has first written a wind design code, largely based on a literature review, has performed wind tunnel tests and advised the application of Eurocodes. This work resulted in the publication of two reports, one dealing with installations on flat roofs and the other with pitched roofs. As a next step, an additional research programme is under development in order to have a more precise evaluation of the wind effect on solar panels. For the technical and practical aspects of execution, a technical note is being developed.

Transferability of experiences to other construction sites/other countries: Collaboration between experts from France, Belgium, UK and Germany has taken place in the context of ISO TC 128 WG03. Any further step in the comprehension of the wind effect on solar installations would be collectively beneficial. Similar guidelines are probably also useful for other countries where such guidelines are not yet available.

Results/consequences of the study: Development of guidelines and standards for the installation of PV panels.

B2 *Belgian study on building airtightness [New Example]*

Reported by: Arnold Janssens, Jelle Laverge, Ghent University

Covered areas: Building airtightness, comparison of 'mainstream workmanship' and 'engaged marked'

Date of study: 2014

Summary: The study was performed by Ghent University in order to study the evolution of achieved air tightness in building practice as a function of construction date, and in order to study the difference between 'mainstream' workmanship and results obtained by the 'engaged' market. The study is based on airtightness measurements in 44 randomly selected, standard new built single family houses in Belgium ('group 1' in Figure 1). The results are compared with those from a previous study in the early 1990's (SENVIVV), with a database that was compiled with results from 161 air tightness reports executed on newly built dwellings by private party consultants ('group 2'), and with the entries in the governmental EPBD-database (1884 measurements).

The results show that the mean leakage rate is about 6 ACH50 for the randomly selected houses ('group 1') and 3 ACH50 for the houses in the databases (EPBD and 'group 2'). The houses in the databases are tested upon the initiative of the owner and are a reference for dwellings that are intended to be airtight. Therefore, the attention to airtight workmanship is substantially higher for these cases than in the randomly selected houses. However, compared to the situation in the 1990's the results show that the airtightness achieved in current construction practice has improved in general.

The results demonstrate the substantial difference between the air tightness achieved by 'mainstream' workmanship and results obtained by the 'engaged' market. Since a large portion of the leakage can be

attributed to differences in design and workmanship measures are needed to improve the quality of both and further improve airtightness of buildings. The results further show that when a pressurisation test is required by the owner, the designer and contractor improve the workmanship, even when no airtightness requirement is imposed.

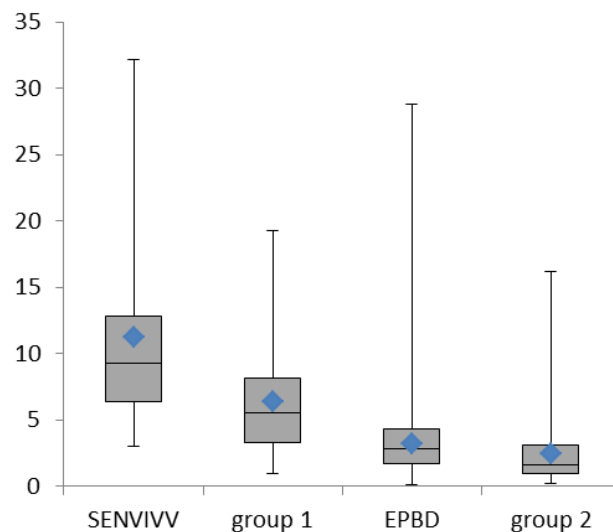


Figure 1: Air leakage rate in single-family houses

Transferability of experiences to other construction sites/other countries: Similar results can be expected for other countries.

Results/consequences of the study: One of the Belgian regions is considering the possibility to relate the systematic measurement of building airtightness to requirements for Nearly Zero Energy Buildings.

References: [23]

B3 Quality of installation of thermal insulation in cavity walls in Belgium [New Example]

Reported by: Arnold Janssens, Ghent University

Responsible author/organisation of the study: H. Hens, J. Lecompte, S. Roels (KULeuven)

Covered areas: Incomplete or incorrectly installed insulation layer: gaps, uneven surfaces; joints not realised with insulation

Date of study: 1990-2014

Summary: When thermal insulation is installed in a cavity wall construction, special attention must be paid to the absence of residual cavities surrounding the layer. Otherwise a considerable increase of the heat transfer can be expected, due to air flows around and through the insulation layer, caused by natural convection (Lecompte 1990). In case of poor workmanship, the use of insulation boards introduces the presence of joints between the boards themselves and between the boards and other components, coupled with the residual air layers on both sides of the insulation resulting from the uneven surfaces of cavity facing masonry construction. In a large number of experimental studies performed in the laboratory and in the field in between 1985 and 2000, the laboratory of building physics at KULeuven showed that the U-value of cavity walls increase substantially as a result of incorrectly installed insulation layers, [15]. The overall U-value may be a factor 4 higher than the design U-value of 0.2 W/m²K in case a 10 mm residual cavity is present in between the insulation layer and the inner masonry leaf, and 10 mm wide gaps exist in between the insulation boards. At the time, gaps and cavities with a width of this order of magnitude could be easily found in most construction sites. This was caused by the fact that masons were insufficiently trained to handle and install thermal insulation, and that the traditional construction sequence with internal scaffolding was not adequate to allow for a correct installation of insulation boards. As a result of the findings of the KULeuven the construction practice in Belgium has changed since the 1990's, with improved training of masons and an optimized construction sequence. The correct sequence is to construct first the inner leaf paying attention to the evenness of the cavity facing surface,

then fixing the insulation layer by pressing it against the inner leaf using screwed cavity ties and by interlocking and taping joints between boards, and finally constructing the brick veneer (see figure). Thermal insulation manufacturers also provide improved board designs with tongue-and-groove joint systems and compatible tapes to assist correct installation.

In 2014 KULeuven organized a follow-up study to investigate the workmanship in recent cavity wall construction with design U-values below $0.3 \text{ W/m}^2\text{K}$, [42]. They analysed the occurrence of installation errors at 21 construction sites of single family houses. None of the sites was completely flawless. The more prevailing problem was the presence of a residual air gap in between thermal insulation and inner leaf caused by irregularities in masonry construction. The average width of this gap was in the order of 1-3 mm. Small gaps in between insulation boards were also observed together with an inadequate application of tongue-and-groove systems. In 3 out of 21 sites (14%), workmanship was more problematic with gaps up to 5 and even 10 mm in between boards. These were sites where the home-owner was involved in construction (DIY). Based on numerical simulations the study however showed that the installation errors found at most sites (order 1-3 mm) did not have a significant impact on thermal performance. The installation errors found in the 3 problematic sites would still increase average U-values by a factor 2. So although workmanship has improved compared to the practices found 20 years ago, it is still a point of attention.



Figure 2: Installing cavity wall insulation: poor (left) versus good (right) workmanship

The occurrence of installation errors was widespread, but as the follow-up study in 2014 showed, the extent of the errors has decreased, although none of the construction sites investigated was completely flawless.

Transferability of experiences to other construction sites/other countries: Similar results can be expected for other countries.

Results/consequences of the study: The study has changed cavity wall construction practice with improved training of masons, a change in construction sequence and product development.

References: [15], [24], [42]

C1 *Cypriot analysis of the National Status Quo within BUILD UP Skills*

Reported by: Marina Kyprianou Dracou, The Cyprus Institute.

Responsible authors of the study: Cyprus Energy Agency, Cyprus Productivity Centre, Cyprus Organisation for Standardisation, Human Resource Development Authority of Cyprus, Cyprus Institute of Energy, Technical Chamber of Cyprus, Federation of Associations of Building Contractors Cyprus, Cyprus Labour Institute, Cyprus Workers' Confederation, Cyprus Chamber of Commerce and Industry

Covered areas: Insufficient knowledge of new technologies, construction workers not adequately trained, necessary specialists not part of the construction team

Date of study: November 2011 - July 2012

Summary: The aim of the study and subsequent report was the analysis of the status quo of the building stock in Cyprus and its energy performance and the comparison with the national targets for 2020, in order to identify the barriers and gaps that the construction sector is facing, with special focus on

employees' skills, for the achievement of the energy targets of Cyprus. According to the study, the total employment needs of the period 2010-2020 in selected technical occupations related to the "Build Up Skills" project are expected to increase significantly in comparison to the respective needs of the period 2005-2010.

The report presents the status quo regarding the construction and energy sectors and also identifies the barriers and gaps in reaching those targets as regards the workforce in the construction sector, which may hinder the achievement of the relevant targets. Finally, it provides estimates on the employment and skills needs of technical occupations. It is important to mention that the barriers recognised in the report are classified in three categories relating to:

1. the broader institutional and economic environment;
2. the characteristics of the construction sector, and;
3. the quantitative and qualitative fulfilment of skills needs.

Specifically, regarding the third category, with which we are mostly concerned, the report analyses it into the following three sub-categories:

- a. low enrolment percentage in technical vocational education;
- b. technical vocational education and training infrastructure and trainers, and;
- c. absence of a framework for the regulation and certification of technical occupations.

Transferability of experiences to other construction sites/other countries: If the problems regarding the workforce in the construction sector in Cyprus continue to exist, they will continue to affect the quality of works regarding renovations in existing buildings as well as the quality of works regarding a huge number of new buildings. This will result in not achieving the targets for energy and buildings by 2020, which except from an environmental impact, will have a huge financial impact as well.

Results/consequences of the study: The report concludes that the set targets for energy and buildings are deemed to be attainable, but only on the condition that the necessary legislative and regulatory provisions will be promoted and the required structures for control and certification will be created. Moreover, it is necessary to continuously monitor the sector's enterprises' needs in adequately skilled and trained human resources, as well as to take measures to meet these needs. The results of the report formed the basis for the preparation of a Roadmap with a time horizon for completion by 2020 which includes all main policies and actions required for the identification and promotion of the required vocational education and training of employees in the construction sector and other relevant sectors, so that they acquire the necessary skills to actively contribute to the achievement of national targets for 2020, regarding energy and buildings.

References: [7]

D1 *Burgholzhof study, Germany*

Reported by: Heike Erhorn-Kluttig, Fraunhofer Institute for Building Physics, Germany

Covered areas: Insulation material, quality of windows, thermal bridges, window seams, roller shutters

Date of study: 2002

Summary: Between 1996 and 2002 about 500 residential units were built as low-energy multi-family houses at a new city quarter of Stuttgart, the Burgholzhof. Fraunhofer Institute for Building Physics was contracted by the city to check the calculations for the proof of thermal protection, the detailed design of joints and the realisation on the construction site. The calculated and the measured heating energy data were compared and were found to agree nicely, on average. The exercise showed however that a quality check for all three parts (energy performance calculation, planning of details and realisation on the construction site) was necessary in order to guarantee the required performances. Nearly all proofs of thermal protection had to be corrected, sometimes up to 4 times, many of the checked details had to be redrawn or clarified by adding material descriptions, etc. Concerning the realisation on the construction site the following critical points have been gathered:

- ✓ *U-values and g-values of the windows* did not meet the specifications of the proof of thermal protection. At that time this was linked to two official types of U-values for glazings, one defined in

the DIN standard measured for a standard sized window and one in the Federal Gazette including a safety margin for different sizes which had to be used for the calculations of the certificate. The contractors bought and installed the windows with the glazing U-value based on the DIN standard. Thus it was in most cases about 0.1 W/m²K worse than required. G-values have also been a problem as they were regarded as less important by the contractors (as long as the U-values were the “right” ones). The g-values are also not part of the documentation on the glazing or the delivery receipt. In terms of thermal insulation the frame material group that influences the U-value of the windows was sometimes worse than planned.

- ✓ The *thermal separation of balcony plates* was often not realised with the necessary accuracy. This led to gaps between the thermal insulation levels that were filled with mortar or concrete, which resulted in thermal bridges. If the thermal separation was part of pre-fabricated balconies, damages on the construction site often took place, leading to thermal bridges as well.
- ✓ Based on discussions with the architects, an *overlap of the wall insulation on the window frame* of at least 4 cm was designed and documented in the details. Yet on the construction site the workers realised the overlap with only about 1 cm insulation overlapping. They understood the overlap (though differently drawn on the designs) as a total overlap including plaster etc., and the window installers fixed their rolling shutter tracks directly at the end of the windows. The result was an increased danger of rain water entering the insulation material and also a higher thermal bridge effect.
- ✓ *Windows seams* have been filled with polyurethane foam only. This is not expert working. The foam is not durably elastic. It was documented that the foam showed holes already a few days after the installation. The result is bad airtightness of the window joints. In Germany an installation guideline (see best practice example G) of the *RAL-Gütegemeinschaft Fenster und Haustüren* exists that gives good guidance on how to install windows correctly. The guideline is an acknowledged rule of technology and is being transferred to other countries (e.g. Croatia) as well.
- ✓ Building site visits have shown that partly *insulation material with an inferior thermal conductivity* than planned was used. Seldom, *smaller insulation thicknesses* than planned were applied. This has been supported by the product information labels. While the thickness is often printed in large font, the thermal conductivity is included in small fonts.
- ✓ Wall insulation behind claddings (curtain walls) often included a significantly *higher ratio of lattice* than included in the calculation of the U-value.
- ✓ *Top mounted roller shutters* create thermal bridges because the shutter boxes are installed on top of the wall area without any thermal insulation. The U-value that was used for the shutter boxes does not include the increased heat flow through the shutter box into the wall at the side areas. This can only be solved if thermal insulation is added on the construction site. Front mounted shutters are an alternative solution.
- ✓ The *additional insulation on the inner side of cellar walls* at the ceiling to reduce thermal losses of the ground floor often interfered with pipes and cellar fixtures. This has to be designed more carefully in advance or the insulation has to be part of the walls (insulation band as inlay of the casing)



Figure 3: Photo of the low energy housing estate Stuttgart-Burgholzhof that was constructed between 1996 and 2002. (Source: Fraunhofer IBP)

Transferability of experiences to other construction sites/other countries: At the time of their realisation, the low energy buildings have been designed 30 % better than what was required based on the thermal decree in Germany. Nowadays, the German energy performance requirements are nearly at the same level than what was realised at the Burgholzhof. About 10 years of experience and the multiplication of realisations have probably resulted in less training needs of the work force and maybe less faulty realisation at the construction site. However, it has to be assumed that many of these problems can still be found on today's construction sites and also in other European countries.

Results/consequences of the study: The different U-values of glazings (measured according to the DIN standard vs. published in the Federal Gazette) are no longer in use. They have been replaced by new rules following DIN EN ISO 10077 offering fewer possibilities for misunderstandings.

References: [10]

E1 *Estonian analysis of the National Status Quo within BUILD UP Skills*

Reported by: Mikk Maivel, Tallinn University of Technology

Responsible authors of the study: Estonian Institute of Economic Research

Covered areas: Insufficient knowledge of new technologies/construction workers not adequately trained

Date of study: 2012

Summary: The goal of this analysis is to give an overview of how the Estonian construction sector developed and of what it is now, its legal and political background, the education system (vocational, higher and adult education) and to describe the workforce's needs for training and qualifications. It lists possible obstacles found during the analysis, which are related to qualification of employees in the construction sector and which may have the most influence on the achievement of the "Estonia 2020" objectives in seeking energy efficiency. The outcome of this research is an input for the next stage of the project, in the course of which a roadmap of in-service training and other training in Estonia will be prepared along with an action plan up to 2020. It will lay a basis for developing national in-service training, training programmes and qualification system in the construction sector, and these will be developed hand in hand with relevant associated groups as well as other participants in the construction market. The main goal of preparing the roadmap and action plan is to encourage national groups to offer training, to expand and update the existing qualification requirements and to raise the level of in-service training in the construction sector, taking into account the development trends in Europe in this field. According to workforce study data, construction workers who lack professional training account for close to 50 percent of workers at construction companies.

The study shows the importance of developing the construction education. The workforce study data signal an urgent shortage of workforce in the sector - close to one-half of companies (48 %) said they needed an employee or more immediately. The forecasts for 2012-2020 compiled on the basis of the overall numbers of people employed at construction companies indicate that the average number of the employed is 42,000-47,000 workers per year. Forecasts made on various assumptions show that the number of employed by construction companies could rise to 45,000-50,000 people or more. For this reason, the construction sector would need, starting already in 2012, at least 935-1,200 new skilled workers per year, which makes up close to 3 % of the entire workforce.

Transferability of experiences to other construction sites/other countries: Though the situation might be similar in neighbouring countries it is clearly a national analysis of the current situation and the needs for workforce.

Results/consequences of the study: The study goal is to give an overview of the real situation and as a result it is important to increase the skilled workforce share in the construction market. The Ministry of Economic Affairs and Communications and the Ministry of Education and Research will consider the basic results in their further development plans.

References: [27]

E2 *Estonian housing stock technical condition – apartment buildings built during the period 1990-2010 (project HOONEF)*

Reported by: Mikk Maivel, Tallinn University of Technology

Responsible author of the study: Targo Kalamees, Tallinn University of Technology

Covered areas: Insulation material, damages on construction site, wet insulation, waterproof layers, built in moisture, moisture and air barriers, joints.

Date of study: 2010-2012

Summary: The analysis includes a comprehensive study of 41 existing apartment buildings which were built during the years of 1990-2010. Main chapters investigate: indoor quality; construction quality; building service systems; transmission characteristics; energy consumption etc. One chapter focused on field investigations in seven construction sites with the goal to identify the main critical situations. The main critical areas were:

- ✓ wrong (insulation) material: λ -value, thickness, etc.;
- ✓ damages of insulation material during construction;
- ✓ wet (insulation) material: storage on site, protection during construction;
- ✓ incorrect waterproof layers in wet areas (bath rooms, etc.);
- ✓ not enough drying time for built in moisture (concrete, wood);
- ✓ incomplete air or moisture barrier;
- ✓ damages of air or moisture barrier during the implementation;
- ✓ joints not watertight/airtight;
- ✓ wrong (insulation) material: water resistance;
- ✓ wrong (insulation) material: pressure resistance;
- ✓ joints between windows and walls not insulated;
- ✓ joints between windows and walls not watertight/airtight.

After construction time the two year warranty time periods were also observed. Seven buildings were involved comprehensively.

Transferability of experiences to other construction sites/other countries: National, countries with similar constructions and climate, some of the problems are international

Results/consequences of the study: The study report is published and it is possible to download it from the Internet. It refers to the critical situations and it gives good guidelines for designers and builders.

E3 *Quality of ventilation systems in residential buildings: status and perspectives in Estonia*

Reported by: Mikk Maivel, Tallinn University of Technology

Responsible author of the study: Alo Mikola, Tallinn University of Technology

Covered areas: Ventilation systems: Joints not airtight, no accessibility for cleaning/maintenance, wrong settings, filters not included

Date of study: 2013

Summary: This scientific paper was prepared based on several relevant studies. The main focus of the paper is to describe critical situation in Estonian apartment buildings ventilation systems. It compares measured values with relevant standard values (EN 15251) and it describes the overall ventilation market including commissioning and designing processes related to dwellings. The paper addresses old apartment buildings as well as new ones. Investigations outline different problems for simple natural stack ventilation systems and even for advanced mechanical exhaust-supply apartment based ventilation system.

In Estonia approximately 63 % of the inhabitants live in apartments with serious indoor climate problems, including:

- ✓ joints between windows and walls not watertight/airtight;
- ✓ no accessibility for cleaning;

- ✓ joints with other system components not airtight: fan, AHU;
- ✓ wrong air flow rate settings, setting on default instead of specific necessary setting;
- ✓ required filters not included;
- ✓ installation without accessibility for maintenance.

Transferability of experiences to other construction sites/other countries: National, partly international

Results/consequences of the study: The studies resulted in guidelines for HVAC designers and builders.

References: [25]

EU1 *EU project SAVE-DUCT*

Reported by: Samuel Caillou, Clarisse Mees, BBRI

Covered areas: Ductwork, airtightness

Date of study: End of 1990s

Summary: The EU SAVE-DUCT project analysed airtightness measurements of ductwork. Duct leakage is detrimental to energy efficiency (heat losses and electric consumption of the fans), comfort, ventilation effectiveness, indoor air quality, and sometimes even to health. Measurements of 21 ventilation systems in Belgium, 21 systems in France and 69 systems in Sweden were done. Analysis made on specific cases showed that the overall performance of the systems is drastically affected when the ducts are leaky. In France and Belgium on average 20 % of the nominal airflows was lost due to poor airtightness of the ductwork. The analysis in Belgium led to the assumption that rectangular ducts result in higher air leakages than circular ducts. However, it is possible and easy to install tight duct systems with commercially available quality products. In Sweden, where factory-fitted sealing gaskets are widely used, airtightness Class C is commonly required and fulfilled. Furthermore, the additional investment cost (if any) for these products is probably not very significant since the labour cost is considerably reduced.

Transferability of experiences to other construction sites/other countries: The situation appears to be quite satisfactory in Sweden compared to other countries: both under energy aspects and under economic aspects. The Swedish experience could be transferred to other countries.

Results/consequences of the study: Installations using conventional in situ techniques such as tape or mastic are not satisfying. There is a need for harmonised ductwork airtightness tests and analysis protocols. The generalization of circular ducts and factory-fitted sealing gaskets is recommended.

EU2 *EU project solar thermal systems – CombiSol*

Reported by: Susanne Geissler, OEGNB

Responsible authors of the study: AEE INTEC, INES Education, CEA Ines, SERC, ITW, PlanEnergi

Covered areas: Installation of solar thermal systems

Date of study: 2007-2010

Summary: 70 installed solar thermal systems in Germany, France, Sweden and Austria have been selected to be qualitatively evaluated. After the qualitative inspection, 45 solar thermal systems have been monitored in order to track their real performances. The project was funded by IEE and co-funded by the Austrian Federal Ministry of Transport, Innovation, and Technology; December 2007 - December 2010.

Conclusions:

- ✓ Evaluation results met the expectations regarding solar yield and solar coverage.
- ✓ System performance needs to be improved: e.g. mistakes regarding the integration of the solar thermal system in the heating circuit can lead to the unwanted continuous operation of the gas condensing boiler; high temperatures in summer can lead to unwanted hot water flow, heating up the building.

Transferability of experiences to other construction sites/other countries: International. The test included systems from 4 different countries

Results/consequences of the study: Among others, the project resulted in the development of guidelines for manufacturers and installers to avoid mistakes detected during the evaluation and to improve system performances.

References: [37]

EU3 *Duct leakage in air distribution systems [New Example]*

Reported by: Raimo Simson, Tallinn University of Technology

Responsible authors of the study: Ecole Nationale des Travaux Publics de l'Etat, Belgian Building Research Institute, Scandiaconsult, Air Infiltration and Ventilation Centre.

Covered areas: Airtightness of ventilation ducts

Date of study: 1999

Summary: To investigate the implications of duct leakage, a field study was performed on 42 duct systems in Belgium and France. The measurement data confirm the findings of the few earlier experimental investigations on these matters in Europe. In this sample, the leakage rate appears to be typically three times greater than the maximum permitted leakage adopted in EUROVENT 2/2 (Class A). The advantages of tight ducts are illustrated with a theoretical case study on a balanced ventilation system with heat recovery. It indicates that the overall effectiveness of the system reduces drastically if the ducts are leaky. The savings potential of an airtight duct policy at the European level is calculated (a) based on estimates of the number of buildings equipped with mechanical ventilation systems, and (b) assuming market penetration scenarios of rehabilitation techniques.

Observed findings:

- ✓ The tested duct systems are in general very leaky (typically three times leakier than Eurovent Class A). The reason for such poor performances seems to lie in the lack of attention paid to these systems and the technologies adopted. In fact, in these countries, installation is most often done using conventional in situ sealing techniques (e.g. tape or mastic). Therefore, the ductwork airtightness is very much dependent upon the workers' skills.
- ✓ Duct leakage can have a severe impact on the ventilation rates and energy consumption of a building.

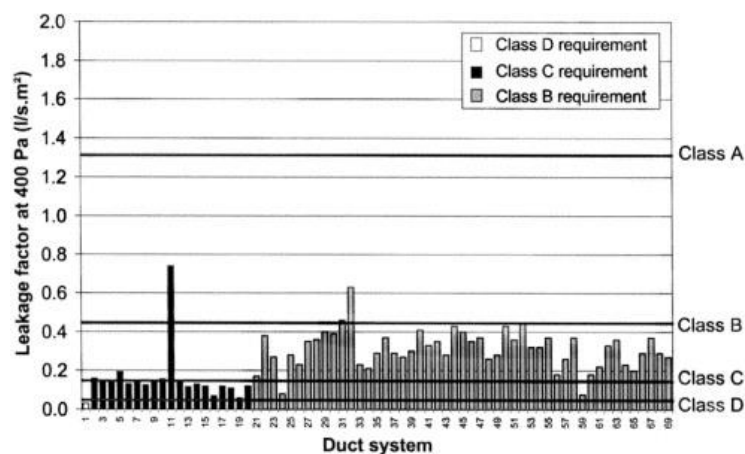


Figure 4: Leakage factor at 100 Pa for the investigated systems in Belgium.

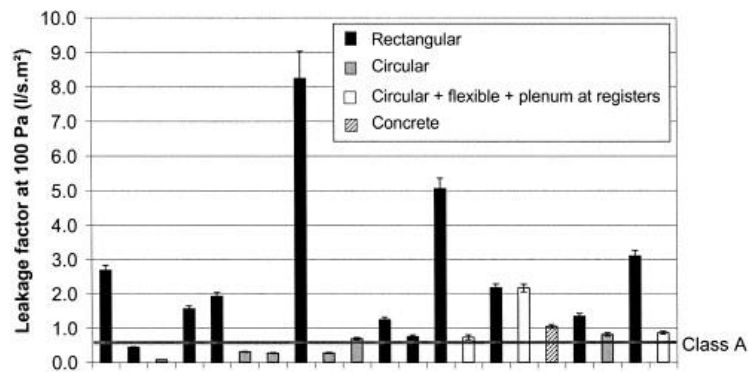


Figure 5: Leakage factor at 100 Pa for the investigated systems in France.

Transferability of experiences to other construction sites/other countries: International.

Results/consequences of the study:

- ✓ A major barrier towards tighter systems lies in cost issues.
- ✓ Additional investment cost (if any) for quality-products should be looked at along with the potential savings on labour cost. In addition, significant energy savings can be achieved with tight ducts, which will have a positive effect on the Life Cycle Cost of the system.
- ✓ The analyses presented show that ventilation and energy use implications of leaky ducts in European buildings are also very large and merit further examination.

References: [6]

F1 CETIAT study on common problems with heat pumps

Reported by: François Durier, CETIAT

Covered areas: Heat pumps

Date of study: 2009

Summary: In the framework of a study about the impact of the quality of works concerning the energy performance of heat pump installations, four French court experts were interviewed by CETIAT. The objective was to identify the most common problems encountered in legal disputes and expertise mandated by the court where malfunctioning of domestic heat pumps installations occurs.

According to these experts, the most common problems related to the quality of the works in domestic heat pump installations in France are:

- Oversizing of the heat pump capacity in the case it has been chosen by the installer (i.e. without detailed study of the heating needs).
- Too low quantity of refrigerant inside the appliance.
- No technical documentation provided to the user about the installation (technical documentation of the heat pump, drawings of the hydronic circuit, electrical diagram of the installation).
- No information provided to the user about the commissioning of the installation.
- For air to water heat pumps:
 - ✓ wrong positioning of the outdoor unit, with insufficient passage for the fresh air and/or recycling of the fresh air flow;
 - ✓ absence of a drain to evacuate condensates;
 - ✓ in some cases, no electrical connection of the electrical heating backup electrical resistance;
 - ✓ wrong adjustment of the defrosting cycle times.
- For water to water heat pumps:
 - ✓ undersizing of the primary circuit water pump or too low primary water flow rate.
- For ground source heat pumps:
 - ✓ undersizing of the surface of the ground collectors.

The interviewed experts point out that very few problems occur at installations carried out by installers that hold the quality label QualiPac.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the French situation for domestic heat pump installations.

Results/consequences of the study: The French installers may choose to be qualified under the quality label QualiPac, which helps them to improve the quality of their work and to prove to their clients that they have the required skills.

F2 *Quality of ventilation systems in new dwellings [New Example]*

Reported by: François Durier, CETIAT

Responsible authors of the study: CETE de Lyon.

Covered areas: Ventilation systems

Date of study: 2013 - 2016

Summary: This analysis, based on French regulatory compliance controls and performed only on ventilation regulation (among 7 other regulations including energy performance), gives clear information about ventilation dysfunctions localisation and qualification. Up to now, only 1.287 dwellings have been analysed through 373 control reports performed between 2008 and 2011. Nearly all dwellings of the sample are equipped with simple exhaust mechanical ventilation. Humidity demand-controlled ventilation accounts for 74% of the sample. Balanced ventilation is found only in 10 single-family dwellings. The statistical analysis of this sample reveals that 604 dwellings out of 1.287, that is 47% of the sample, do not comply with the ventilation regulation. It also means that 47% of the sample present at least one non-compliance remark. The non-compliance rate is 68% for single-family dwellings, and 44% for multi-family dwellings.

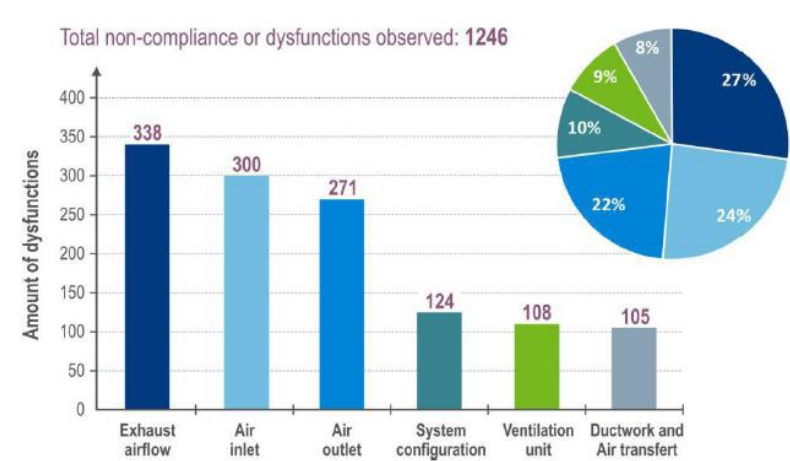


Figure 6: Ventilation dysfunctions

Observed findings:

- ✓ ventilation installation verification is rarely planned during the construction phase;
- ✓ ventilation system commissioning control is not systematic or is incomplete;
- ✓ in-site ventilation system mounting is often far from the expected quality;
- ✓ even if adapted industrial solutions are available, ventilation system dysfunctions are very frequently observed

Lessons to be learned:

- ✓ Ventilation commissioning is an absolutely necessary step to ensure a well working installation upon receipt, with an in-use performance corresponding to the planned one.
- ✓ Many dysfunctions could be avoided through the implementation of quality management tools.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the French situation for ventilation systems.

Results/consequences of the study:

- ✓ The on-going “VIA-Qualité” project will go further on reasons and solutions to improve ventilation systems quality once these are installed.
- ✓ The French Effinergie+ label plans to reinforce ventilation controls, introducing ventilation airflows and duct leakage measurements at commissioning.

References: [17]

F3 *Quality of large solar thermal domestic hot water systems [New Example]*

Reported by: François Durier, CETIAT

Responsible authors of the study: IZUBA energies on behalf of regional authorities and ADEME.

Covered areas: Solar thermal systems

Date of study: 2013 - 2016

Summary: Fifteen large solar thermal hot water systems used for dwellings, hotels or residences for elderly people have been audited in 2013. Numerous problems have been identified on the audited installations:

- ✓ wrong dimensioning or design;
- ✓ low thermal insulation of piping;
- ✓ low insulation of the water storage tanks;
- ✓ errors or weak points in the design and installation of the hydronic circuits;
- ✓ no technical documentation available, lack of maintenance;
- ✓ no measurement devices to check the performance.

Energy performance results are available for 9 installations: 3 of them have a high performance, 3 have a good performance and 3 a low performance.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the French situation for large solar thermal domestic hot water systems.

Results/consequences of the study: The authors of the study propose among others the following actions that should improve the situation:

- ✓ training;
- ✓ quality insurance procedures;
- ✓ systematic commissioning and maintenance;
- ✓ continuous measurements to know and follow the performance.

F4 *Quality of solar thermal domestic hot water systems in houses [New Example]*

Reported by: François Durier, CETIAT

Responsible authors of the study: Qualit'EnR

Covered areas: Solar thermal systems

Date of study: 2007 - 2012

Summary: French installation companies of solar thermal systems can apply for the qualification QualiSol, in order to show to customers their skills for installing these systems. The quality label Qualisol is managed by the French association Qualit'EnR. Each certified company is submitted to an audit by Qualit'EnR, at least once every three years. The audit consists in looking at the actual quality of an installation.

Between 2007 and 2012, 11.817 installations with a solar thermal domestic hot water system have been audited. The results of the audits operated in 2012 on solar thermal domestic hot water systems (their number is not indicated) show that:

- ✓ 93% of the audited installations have an excellent (70%) or good quality (23%);
- ✓ the quality is insufficient for 6% of the audited installations (orange);
- ✓ 1,5% of the audits show a failing installation.

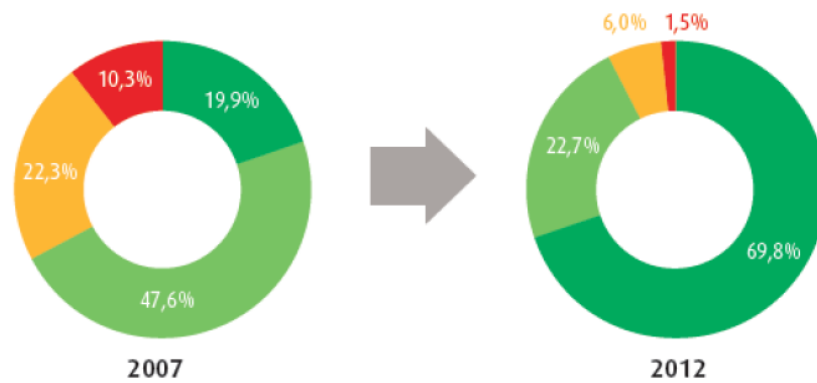


Figure 7: Results of the audits operated in the years 2007 and 2012 by Qualit'EnR on solar thermal domestic hot water systems under the quality label Qualisol. (dark green: excellent, light green: good, orange: insufficient, red: failing)

The most frequent failures were:

- ✓ no indication of the trademark and type of the antifreeze liquid used;
- ✓ safety valve not fitted to the container;
- ✓ container under safety valve not empty or not marked.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the French situation for solar thermal domestic hot water systems.

Results/consequences of the study: Qualit'EnR has developed check-up files that help the installer to control the quality of his own work. A help line is also available for technical advice. The journal "Qualit'EnR infos" regularly includes reminders about good practice, based on the failures that have been found during the audits.

F5 Quality of photovoltaic installations [New Example]

Reported by: François Durier, CETIAT

Responsible authors of the study: Qualit'EnR

Covered areas: Photovoltaic systems

Date of study: 2012

Summary: French installation companies of solar photovoltaic systems can apply for the qualification QualiPV, in order to show to customers their skills for installing these systems. The quality label QualiPV is managed by the French association Qualit'EnR. Each certified company is submitted to an audit by Qualit'EnR, at least once every three years. The audit consists in looking at the actual quality of an installation. In the year 2012, 294 installations with a solar photovoltaic system have been audited.

The results of these 294 audits of solar photovoltaic installations show that:

- ✓ 77% of the audited installations have an excellent (41%) or good quality (36%);
- ✓ the quality is insufficient in 15% of the audited installations;
- ✓ 7% of the audits show a failing installation.

The most frequent failures concerned the electrical installation and safety aspects:

- ✓ signalling not present or not complete;
- ✓ equipotential bonding not correctly achieved;
- ✓ no or incomplete mechanical protection on the accessible wires.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the French situation for photovoltaic installation.

Results/consequences of the study: Qualit'EnR has developed check-up files that help the installer to control the quality of his own work. A help line is also available for technical advice. The journal "Qualit'EnR infos" regularly includes reminders about good practice, based on the failures that have been found during the audits.

F6 *Quality of domestic wood boiler installations [New Example]*

Reported by: François Durier, CETIAT

Responsible authors of the study: Qualit'EnR

Covered areas: Wood boiler

Date of study: 2012

Summary: French installation companies of wood boilers can apply for the qualification Qualibois, in order to show to customers their skills for installing these appliances. The quality label Qualibois is managed by the French association Qualit'EnR. It applies to wood boilers but also to independent wood heating appliances (fireplaces, stoves). Each certified company is submitted to an audit by Qualit'EnR, at least once every three years. The audit consists in looking at the actual quality of an installation. In the year 2012, 208 installations with a domestic wood boiler have been audited.

The results of these 208 audits of domestic wood boiler installations show that:

- ✓ 97% of the audited installations have an excellent (61%) or good quality (36%);
- ✓ the quality is insufficient in 3% of the audited installations;
- ✓ there is no failing installation.

The most frequent failures were:

- ✓ no disconnecting device on the water filling circuit;
- ✓ draught moderator on the flue gases exhaust not correctly installed
- ✓ incorrect ventilation openings for the room in which the boiler is installed.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the French situation for wood boiler installation.

Results/consequences of the study: Qualit'EnR has developed check-up files that help the installer to control the quality of his own work. A help line is also available for technical advice. The journal "Qualit'EnR infos" regularly includes reminders about good practice, based on the failures that have been found during the audits.

F7 *Quality of domestic heat pump installations [New Example]*

Reported by: François Durier, CETIAT

Responsible authors of the study: Qualit'EnR

Covered areas: Heat pumps

Date of study: 2012

Summary: French installation companies of heat pumps can apply for the qualification QualiPAC, in order to show to customers their skills for installing these appliances. The quality label QualiPAC is managed by the French association Qualit'EnR. Each certified company is submitted to an audit by Qualit'EnR, at least twice every three years. The audit consists in looking at the actual quality of an installation. In the year 2012, 319 installations have been audited.

The results of these 319 audits of domestic heat pump installations show that:

- ✓ 74% of the audited installations have an excellent (61%) or good quality (13%);
- ✓ the quality is insufficient in 19% of the audited installations;
- ✓ almost 7% of the audits show a failing installation.

The most frequent failures were:

- ✓ no completion check report available;
- ✓ no commissioning report available;
- ✓ no thermal insulation for pipes and fittings in unheated spaces.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the French situation for heat pump installation.

Results/consequences of the study: Qualit'EnR has developed check-up files that help the installer to control the quality of his own work. A help line is also available for technical advice. The journal "Qualit'EnR infos" regularly includes reminders about good practice, based on the failures that have been found during the audits.

NL1 *Performance and quality of mechanical ventilation in dwellings [New Example]*

Reported by: Raimo Simson, Tallinn University of Technology

Responsible authors of the study: BBA Indoor Environmental Consultancy, Eindhoven University of Technology, Center for Environmental Health

Covered areas: Ventilation systems

Date of study: 2012

Summary: A Dutch national study analysed the performance of mechanical ventilation systems. Ventilation systems with natural supply and mechanical exhaust ventilation (MEV) and balanced mechanical supply and exhaust systems with heat recovery (MVHR) were investigated. Surveys were performed in 299 homes, which included visual inspections and measurements of ventilation rates per room and installation noise levels. An additional survey regarding perceived indoor air quality and self-reported health was completed per household.

Observed findings were:

- ✓ In 48% of the dwellings with balanced mechanical ventilation the total air supply rate was insufficient ($<0,7$ litre/s/m²), while the air supply rate in 85% of dwellings was insufficient in one or more rooms in comparison with the Dutch Building Code.
- ✓ Total air exhaust rates were insufficient in 55% of the dwellings with balanced ventilation and in 69% of the dwellings with mechanical exhaust.
- ✓ The exhaust rates in one or more rooms did not comply with the standards in 80% (MVHR) and 76% (MEV) of the dwellings.
- ✓ Noise levels are higher than 30 dB(A) in one or more bedrooms in 86% of homes with MVHR in the setting in which the ventilation system is providing a sufficient ventilation rate ($>0,7$ litre/s/m²) in many dwellings (or in the highest setting if the ventilation rate is insufficient).
- ✓ High noise levels are in part caused by incorrect placement of (flexible) ductwork, for example sharp bends.
- ✓ In most cases, the ventilation unit is placed at position that will increase the chances of ventilation noise (53% of MVHR and 67% of MEV).
- ✓ Silencers are not properly installed on either air supply or exhaust duct (66 of MVHR).
- ✓ Ductwork is not properly installed (48 of MVHR and 40 % of MEV).

In many instances where mechanical ventilation systems show problems, the installer, the contractor, the developer, the architect and the end-user are all to blame. The underlying problems seem to be improper design requirements, a lack of quality assurance, lack of inspection and enforcement of the building code and a too small budget. Another potential factor is the lack of coordination between the design team, the engineer and the installer, leading to contradictions on site that result in compromised installations.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the Dutch situation for the installation of mechanical ventilation systems.

Results/consequences of the study: Process-related recommendations to guarantee better performance of mechanical ventilation systems.

References: [4]

R1 *Romanian analysis of the National Status Quo within BUILD UP Skills*

Reported by: Horia Petran, The National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development (URBAN-INCERC).

Responsible authors of the study: The National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development, Romanian Association of Building Services Engineers, Energy-Cities Romania, Business Development Group, Association of New and Renewable Energy Sources, Vocational Training House of Builders Foundation, Ministry for Regional Development and Tourism. The report was published within the BUILD UP Skills Romania project, co-funded by the Intelligent Energy Europe Programme of the European Union.

Covered areas: Insufficient knowledge of new technologies, construction workers not adequately trained, necessary specialists not part of the construction team

Date of study: November 2011 - August 2012

Summary: The aim of the study and subsequent report was the analysis of the current situation in Romania in the construction sector in terms of the continuing vocational education and training needed in the energy performance of buildings field and the use of renewable energy sources in buildings, in the context of the commitments undertaken by Romania for 2020.

The main feature that emerges from the analysis of the existing training programmes in the energy efficiency field and use of renewable energy sources is that specific training programmes are missing in 'key' trades, necessary for the mentioned purpose, determined essentially by the lack of training standards for these trades. There is no uniform coverage across various sectors of activity; the training market is a reactive market which addresses the identified needs in the short term, depending on workforce demand exercised on the internal and external market. Some of the managers of construction companies claim the restriction of time as reason for the lack of continuity in training programmes in addition to reasons such as: already qualified recruited staff, too costly, too busy personnel (time pressure) and other reasons such as the difficult assessment of vocational education and training (VET) requirements and failing to find an appropriate VET offer.

Regarding the actual needs qualification in construction, related to energy efficiency (EE) and renewable energy sources (RES), the estimation was based on the current number of skilled workers in the construction sector in Romania (about. 207,000 in 2011, of approx. 331,500 total employees in the construction sector), by relevant occupations and professional degrees, and on the needed construction works evaluated starting from a series of scenarios for deployment at national level the relevant actions in the field of boosting the energy performance of building stock and the use of renewable energy in buildings in the context of achieving the energy targets by 2020. Following the analysis performed based on the developed scenarios, the net number of workers needed to be trained in the construction sector to ensure that the 2020 targets taking into account the reserve estimate obtained from other occupations for which the necessary result is zero (negative need for these occupations) is of 9,100 workers under the pessimistic scenario, and 152,000 workers under the optimistic scenario respectively, while the actual number of non-qualified workers (not accounted for) is about 68,000 workers.

The occupations with the highest relevance for EE and RES (requiring substantial completion of existing competencies or skills or even to define new skills, by developing new occupational standards or by completing existing ones) are:

- ✓ building and related electrician;
- ✓ installers (plumbers and pipe fitters, heating, ventilation, air conditioning);
- ✓ insulation worker;
- ✓ window assembler / Fenestration system installer;
- ✓ solar thermal systems installer;
- ✓ solar photovoltaic systems installer;
- ✓ biomass boiler installer;
- ✓ ground source exchangers installer;

✓ heat pump systems installer.

For these occupations the development of qualification schemes is necessary, and the number of courses and trainers are estimated in the report based on the currently available data. In addition, it is necessary to complete other relevant occupations considered in the analysis (e.g., carpenters, concrete workers, bricklayer, plasterer, roofer, plasterboard specialised installer etc.) with specific skills in EE and use of RES systems in buildings.

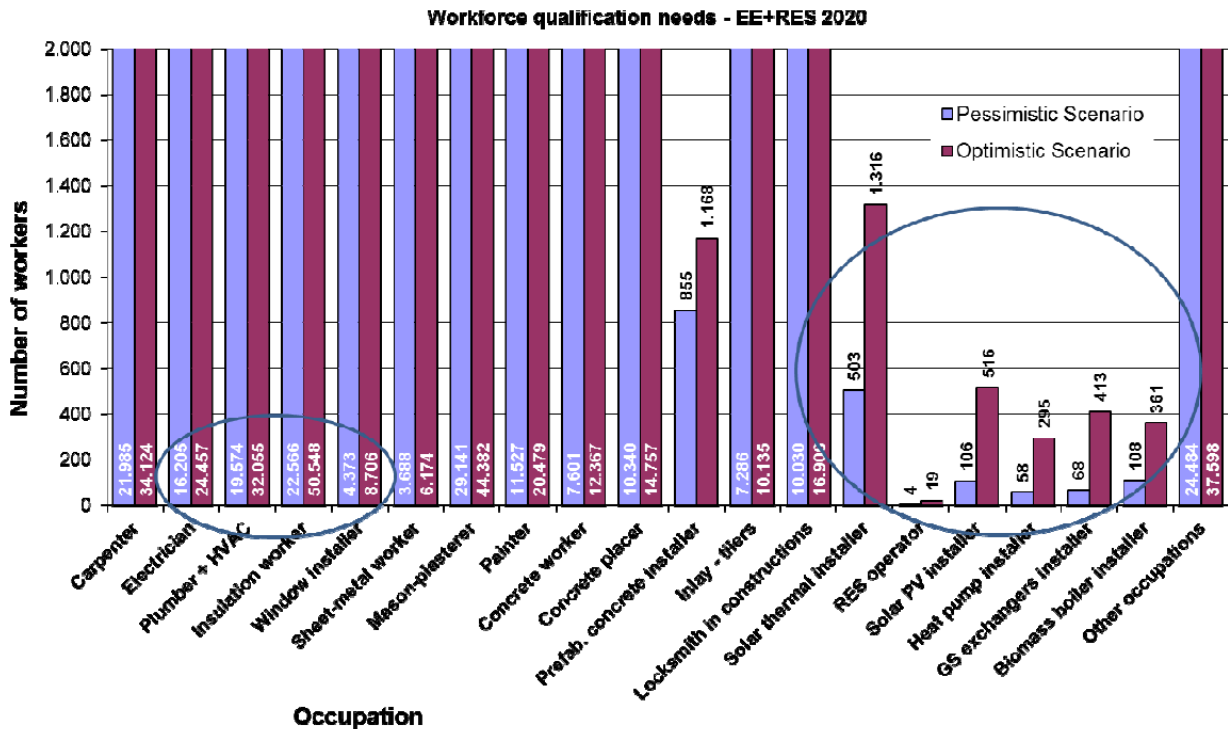


Figure 8: The workforce demand for achieving competence in EE and RES use in buildings. Note: The y-axis ends at 2000 workers. The real values are mostly much higher and given as white and black numbers per bar. (Source: Build UP Skills - Romania. Analysis of the national status quo.)

Transferability of experiences to other construction sites/other countries: Though the situation might be similar in neighbouring countries it is clearly a national analysis of the current situation and the needs for workforce. The methodology used is transferable, as well as the consultation process performed within the National Qualification Platform.

Results/consequences of the study: The study goal was to give an overview of the real situation regarding the workforce qualification in the construction sector in Romania and it served as a starting point for the definition of a national qualifications strategy and for the development of a national qualification roadmap. The roadmap for 2020 was set up starting from eight general objectives depending on the recommended timeframe so that the targets for EE and RES in buildings are reached by the year 2020, and for each objective the necessary actions were detailed, targeted to stakeholders which should either undertake the main responsibilities or the role in influencing the manner in which objectives are to be reached.

References: [28], [29]

S1 Småhuskadenämnden [The Swedish board for moisture and mould damages in single-family houses]

Reported by: Pär Johansson, Chalmers University of Technology

Responsible authors of the study: Folke Björk, Bertil Mattsson and Gudni Jóhannesson, Department of Civil and Architectural Engineering, Royal Institute of Technology (KTH), Stockholm

Covered areas: Time pressure, insufficient knowledge of new technologies/construction workers not adequately trained, incomplete or not correctly installed insulation layer: gaps, uneven surfaces, damages

of insulation material during construction, wet (insulation) material, incorrect waterproof layers in wet areas, wrong (insulation) material: water resistance, incorrect setting of hydraulic flows

Date of study: 2001

Summary: During the years 1986 to 2008 *Småhuskadenämnden - Fonden för fukt- och mögelskador* [The board for moisture and mould damages in single-family houses], helped owners financially to mend damages caused by moisture and mould in single-family buildings younger than 25 years. In this study five damage investigators were interviewed about their experiences of damages and problems in single-family buildings. A survey was sent to more than 100 consultants that had been working for the fund. An evaluation of 100 files in the funds archive was performed and engineers and architects gave information about common technical solutions in new houses. Often the damages were found due to problems with odour in the houses which was the case in 71 % of the files that were investigated.

In many buildings with a *crawl space foundation*, the moisture conditions were poor enough to lead to moisture damages and increased heating demand. That crawl spaces often have moisture damages was confirmed by 94 % of the consultants. The problem could also increase when buildings are energy retrofitted by adding thermal insulation to the ceiling of the crawl space and when the heating system in the house is changed so that the warm chimney stack is no longer warm.

Another problem is *wood treated with chemical preservatives* (e.g. by impregnation) to get better resistance to dry rot in the wood. This preserved wood was used in concrete and in other places with high moisture exposure. However, the preservatives do not protect the wood from mould which will eventually grow on the wood. Damages on preserved wood were found in 30 % of the houses in the files investigated and 95 % of the consultants agreed that the odour from preserved wood is worse than from non-treated wood. The damages lead to increased energy demand for ventilation and when the damages are corrected.

In many buildings *floor heating* has been installed to increase the thermal comfort by raising the floor temperature. Moisture problems can arise when the floor heating is switched off during summer. The energy use increases if the temperature regulation does not function as intended or the foundation is not equipped with enough thermal insulation. The problems are most common when floor heating is added to already existing constructions.

Another common problem in Sweden is *ventilated attics equipped with additional thermal insulation in the attic floor*. Air and moisture leak from the interior of the house to the ventilated attic. Consequences are increased energy use and moisture damages in the wooden materials in the attic, especially in the interior part of the wooden boards in the roof. Of the consultants, 56 % agree that ventilated attics often have moisture problems and 87 % agree that the problems increases when the attic is energy retrofitted.

There are also many damages in houses where the *thermal insulation is located above the concrete slab* and in *basements where the walls have been insulated from the inside with a light-weight construction that include wood*. Houses with a *veneer brick façade often had mortar in the ventilated air space* on the interior surface of the brick. If the load-bearing construction is an insulated wooden construction, the water damages the wood and decreases the insulating ability of the insulation.

Water leakages around windows poses a problem according to 44 % of the consultants. This leads to wet insulation materials and an increased probability for air leakages at locations with details of poor design.

Due to lack of maintenance and too high confidence in the *waterproof layer in wet areas*, 89 % of the consultants agree that these areas often have moisture damages. It is also common that flooring materials are exposed to too high moisture conditions and this leads to bad smell. 73 % of the consultants agree on this fact.

Another problem closely related to the energy use is *built in moisture in the construction*. Time pressure, negligence and poor workmanship (intentional or unintentional) are contributing to the problems with built-in moisture.

In the study 15 % of the houses had moisture damages in the crawl space, 30 % of the houses had preserved wood with mould growth, 44 % had moisture damages in the foundation with thermal insulation located above the concrete slab, 16 % had moisture damages in the furnished basement, 7 % of the houses

had moisture damages in connection to veneer brick walls. The study increased the awareness of problems with too high energy use and health issues in new houses.

Transferability of experiences to other construction sites/other countries: National, countries with similar constructions and climate, some of the problems are international

Results/consequences of the study: If crawl spaces are ventilated by a ventilation system and the ground is better insulated the problem can be reduced in the future. Preserved wood should not be used in buildings, instead change the construction to a less risky one. Foundations with thermal insulation above the concrete slab are no longer used in single family houses. Education and information concerning moisture issues.

References: [5]

S2 *Wrong insulation material at loose fill insulations in attics, Sweden*

Reported by: Paula Wahlgren, Chalmers University of Technology

Responsible authors of the study: FoU-väst part of Sveriges byggindustrier (the Swedish construction federation)

Covered areas: Wrong insulation material regarding λ -value, thickness, etc.

Date of study: 1998

Summary: The aim of the study is to map the status of loose fill insulation in attics and to evaluate the effect of faulty insulation. The result of the study is that:

- ✓ the thickness of attic insulation is lower than ordered in every fourth building;
- ✓ there is damage in the form of cavities, created by for example mice, or decreased thickness due to people stepping on the insulation in 50 % of the buildings;
- ✓ the wind protection has fallen onto the insulation in every fourth building;
- ✓ wind impact (and in some cases people) had caused the insulation to move in 13 % of the buildings; some attic floor areas had no insulation at all;
- ✓ the insulation settlement was in some buildings larger than expected.

In the study, there is also an investigation of the influence of natural convection and forced convection. The conclusion of this investigation is that natural convection rarely occurs in common Swedish loose fill insulation. However, care should be taken if lower densities are used. It is estimated that forced convection can have an impact; a maximum of 10 % increase in heat loss is expected.

The impact of a poor loose fill insulation status is that the transmission losses through the attic floor increase. An example in the study is that insulation that has been stepped on has decreased its insulation performance by 40 %. There is an impact of forced convection but not of natural convection in common loose fill insulation.

Transferability of experiences to other construction sites/other countries: International

Results/consequences of the study: There are some practical recommendations in the study:

- ✓ inform about the situation;
- ✓ use right amount of insulation and save material in the building for future use;
- ✓ the building designer should make a detailed description of the eaves including wind protection;
- ✓ inspect the attic floor once a year (and improve if needed).

S3 *Problems with external thermal insulation composite systems (ETICS), Sweden*

Reported by: Pär Johansson, Chalmers University of Technology

Responsible authors of the study: Ingemar Samuelsson and Anders Jansson, SP Technical Research Institute of Sweden.

Covered areas: Joints not watertight/airtight

Date of study: 2009

Summary: In the 1980s, the Swedish construction industry started using systems with plaster on the exterior of the insulation. These well-insulated, rendered, unventilated and undrained stud walls became very popular in Sweden because of their low cost. Unfortunately the system proved to be prone to moisture damages. The first examples of moisture damages in buildings with this system were found in the early 2000s. The most common damages were found in the exterior plasterboard and in the outer part of the wooden frame. Water that enters the construction at leaky construction details is sucked into the plasterboard or is transported on the exterior or interior side of the board into the construction at cracks and joints. Common points where water enters are at balconies, windows, terraces and roof attachments. The damage is never visible on the surface of the wall, but is hidden within the wall. The only way to detect the damage is to measure the moisture conditions inside the wall. In this study 821 buildings were investigated to find the extent of damages in the Swedish building stock.

Approximately 15,000 to 30,000 buildings have been built with this system. The number of affected dwellings can be up to 160,000 since many multi-family buildings have been built using the system. Of the buildings investigated, 55 % had damages resulting in that at least one entire façade had to be replaced. The cost for repairing the damages was in some cases covered by the building guarantee but in many cases the cost had to be covered by the owner. The energy use increases when the wall contains moisture and when the wall has been repaired the thickness increases due to the drainage and air gap, which also can lead to less room for insulation in the wall.

Transferability of experiences to other construction sites/other countries: National, countries with similar constructions & climate

Results/consequences of the study: It was found that walls with EPS had more damages (57 % of the buildings) than walls with mineral wool (32 %). Also the thickness of the render influenced the number of the damages, where a layer of < 20 mm render was more risky (56 % damaged) than thicker, > 20 mm, plaster walls were (7 % damaged). After the study was presented, drained walls (with or without air gap) are nowadays recommended. If undrained walls are used, the details need perfect execution and that materials susceptible to moisture are not used (i.e. not wood). The following points were also identified in order to construct a moisture safe undrained wall:

- ✓ 20 mm render, capillary active with good drying capability.
- ✓ 8-10 mm render, water repellent with good drying capability.
- ✓ The risk for summer condensation should be evaluated for each project.
- ✓ Render should be attached on mineral wool.
- ✓ Exterior weatherboard should be made of inorganic materials that are water repellent and resistant to mould growth.
- ✓ The studs should be inorganic material.
- ✓ Water repellent details that stop water from entering the floor joist and the upper side of the window and door frame.
- ✓ Careful execution and thorough planning of metal details and attachments in the façade.
- ✓ The interior air and vapour barrier should be airtight.

References: [35], [36]

S4 *The causes and costs of defects in construction, Sweden*

Reported by: Pär Johansson, Chalmers University of Technology

Responsible authors of the study: Per-Erik Josephson and Yngve Hammarlund, Chalmers University of Technology.

Covered areas: General issues, especially lack of motivation/control

Date of study: 1999

Summary: A study made in seven construction companies where the nature of defects detected during production is discussed. Seven building projects have each been monitored during a 6 month-period. Observers spent 8 h a day at the site analysing and describing defects occurring. A total of 2879 defects

have been collected and fully described, including their root causes. Formal interviews with 92 key persons have been made. The study was performed during 1994-1996 as a continuation and deepening of a study carried out during 1986-1990 by the same research group. In the first study, 54% of the defect cost could be attributed to production; 34% to site management and 20% to workmanship. It was clear that it was not lack of knowledge that was the main cause of defects in workmanship, but lack of motivation [14].

The number of defect descriptions varies between 283 and 480 per project. Since some descriptions contain several similar defects, the real number of defects is higher. The defect costs arising during the time of the study vary between 2.3% and 9.4% of the production cost [14].

Transferability of experiences to other construction sites/other countries: Probably international

Results/consequences of the study: The analysis indicates that, on average, 32% of the defect costs originated in the early phases, i.e., in relation to the client and the design. Approximately 45% of the defect cost originated on the site, i.e. in relation to the site management, the workers and the sub-contractors. Approximately 20% of the defect cost originated in defect materials or machines. For design defects, 44% of the defect cost was found to be caused by lack of knowledge, see table 2. For defects in site management, 50% of the cost was caused by lack of motivation. For defects in workmanship, lack of motivation dominated (69%) but risk (i.e. that there is a probability of a defect) was also identified as a cause. For the subcontractors, 47% of the defect cost was found to be caused by lack of motivation [14].

Actor	Knowledge	Information	Motivation	Stress	Risk
Design	44	18	35	2	1
Site management	31	8	50	6	5
Workmanship	12	2	69	1	16
Subcontractors	27	13	47	3	10

*Table 2: Causes of defects for each category of actors (% of defect cost per actor respectively).
(Source: [14]).*

Comparison with earlier studies does not show significant differences. The authors have also mentioned some preliminary results concerning the root causes of the defects: stability in the client organisation, client's project control, user involvement, time pressure, composition of the project organisation, cost pressure, support to the site organisation, to motivate people [14].

The earlier a defect is detected, the lower the cost of correcting it. In the study, it was concluded that 37% of the defects for sure could have been detected earlier in the process while 35% of the defects probably could have been detected earlier in the process. Note that it is only 28% of the defects that could not have been detected earlier. For design defects and defects in site management, 90% and 80% of the defects could have been detected earlier [12].

References: [18], [19], [20], [21]

S5 Factors that affect the building's air tightness, Sweden

Reported by: Paula Wahlgren, Chalmers University of Technology

Responsible authors of the study: Emma Eliasson, Chalmers University of Technology.

Covered areas: Building airtightness

Date of study: 2010

Summary: The aim of the work was to study the factors that affect the building's air tightness and to determine necessary measures to fulfil air tightness requirements for a building's thermal envelope. A number of residential buildings (appr. 30) were studied. Interviews with production managers and production leaders of the projects were made to obtain an overview of how the tightness work has been

executed and also the conditions/awareness that have existed for air tightness in the projects. All information was compared to air tightness results available from fan pressurization tests.

In order to achieve a low air leakage of the building envelope, a focus on air tightness is required in the building project. None of the studied building projects without focus on air tightness reached lower air leakage than 0.4 l/sm² (square meter of exterior envelope area). The study also shows that high commitment from all involved in the production phase considering tightness work will help to achieve a low air leakage. To achieve an air leakage rate of 0.3 l/sm², action should be taken to increase the commitment during production. An early search for leakage in the building can be done to notice shortcomings in the air barrier and to pass on information and improvement opportunities for subsequent performance.

The installation layer (recessed air barrier) is most likely the one technical solution that affects the building envelope's air tightness most. The study shows that an installation layer usually results in an air leakage lower than 0.5 l/sm² and should therefore be used to fulfil a requirement of 0.3 l/sm². A combination of several methods, see following examples, should be used to achieve an air leakage of 0.3 l/sm²:

- ✓ Use metal plate spigots around vents.
- ✓ Plastic foil should be folded into the window recesses and swelling insulation should be used in the connection between external wall and window frame.
- ✓ In the connection between the external wall and bottom slab the plastic foil is clamped with sealing.
- ✓ In order to seal joints, the plastic foil is clamped between solid materials together with butyl rubber strip.
- ✓ With ventilation systems using both supply and extract air (and heat recovery), care should be taken to reduce the number of penetrations through the plastic foil, for example by the use of a suspended ceiling.
- ✓ Risk structures, such as spotlights and interior attic hatches, should be avoided.

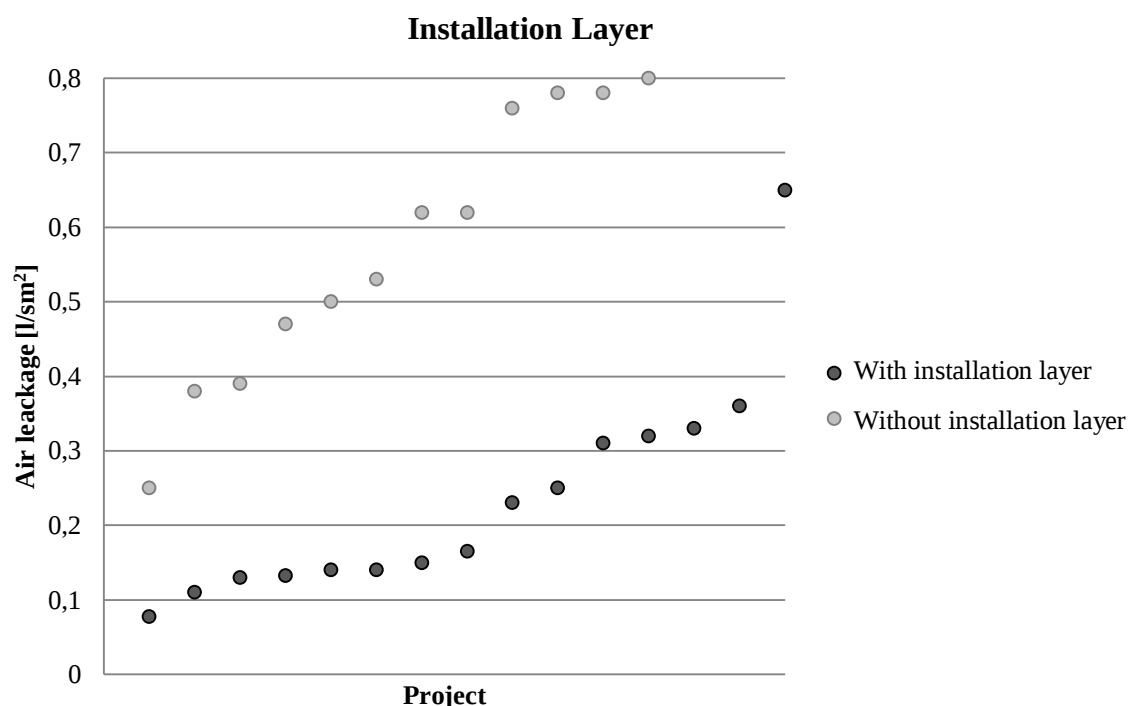


Figure 9: Air leakages of different building envelopes divided into walls with and without specific installation layer. (Source: [8]).

Transferability of experiences to other construction sites/other countries: National, countries with similar constructions & climate

Results/consequences of the study: The critical situations result in a poor airtightness in buildings. The building airtightness can be improved with the above mentioned recommendations. The recommendations

can be applied on both new buildings and renovations. Recommendations have been compiled for the measures that can be done to achieve an airtightness requirement of 0.3 l/sm².

References: [8]

UK1 *Quality of ventilation systems [New Example]*

Reported by: Raimo Simson, Tallinn University of Technology

Responsible authors of the study: BSRIA

Covered areas: Ventilation system

Date of study: 2011

Summary: In late 2011 The Building Services Research and Information Association (BSRIA) undertook a small independent study on 40 random properties constructed by different builders, with various ventilation systems employed to the requirements contained in the 2010 version of the Building Regulations to assess their performance characteristics. It found that that 95% of everything initially evaluated failed to meet the requirements of the Building Regulations with some installations having a number of failure modes, as presented in table 3.

Number of failures	Description of failures
33 (82.5%)	Ductwork incorrectly fitted (kinked/bent/poor joints/excessive length)
10 (25%)	Undersized fans to meet the minimum ventilation requirements
6 (15%)	Insufficient fans or terminal outlets for dwelling type
3	No boost function
3	Incorrect installation data
2	Missing ductwork
1	Blocked ductwork

Table 3: Ventilation system failure modes in a study of 40 dwellings.

The ventilation systems design was regularly compromised with inadequate installation, inspection and commissioning, along with the instrumentation used providing data that was wholly incorrect.

Lessons to be learned:

- ✓ Only firm implementation of the existing Regulations by the Building Control officers are likely to have a significant change on the overall quality of the construction works.

Transferability of experiences to other construction sites/other countries: National. The information is specific to the UK situation for ventilation system installation.

Results/consequences of the study: Steps in the right direction are currently being made, with for example the production of a freely available flow measurement guide.

References: [12]

VI. Best practice examples to solve the critical situations

After showing why and how critical some situations on the construction site are regarding the quality of work, this part deals with some successful national examples that help to guarantee a higher quality of construction and installation work.

Solution	Country	Reported by	Covered areas	Date of solution	Type of solution	Legal/ other	Transferability
Training and certification schemes for installers at AIT	Austria	OEGNB	Installation of heat pumps, PV, solar thermal and ventilation systems	Since 2001	Training and certification of installers	Voluntary, recommended by klimaaktiv	Yes
Guidelines, checklists and commissioning protocols by professional associations	Austria	OEGNB	Installation of heat pumps, PV, solar thermal and ventilation systems	Since ca. 2005	Guideline, checklist, Commissioning protocol	Voluntary	Yes
Voluntary building certification including measurements (TQB)	Austria	OEGNB	Building envelope quality	Pilot phase in 2001, in place since 2003	Quality assessment by third party	Voluntary	Yes
Taking thermal bridges into account in the EPBD-regulation/ Stimulating the building industry to improve thermal detailing	Belgium	Ghent University	Thermal bridges	Since 2011	Guideline, education of workers, legislation	Regulatory, mandatory	Yes
IEE project WE-Qualify	Cyprus	The Cyprus Institute	Knowledge/training, specialisation, material, installation, damages during construction, wet material, roller shutters	2013 + 36 months	Education of workers (training material + training)	Recommendation/ voluntary	In general yes
Scheme of Vocational Qualifications: I have the qualifications. I certify!	Cyprus	The Cyprus Institute	Knowledge/training, specialisation	2013, ongoing	Education and certification of workers	Recommendation/ voluntary	In general yes

Table 4: Overview of collected best practice examples regarding quality assurance on construction sites.

Solution	Country	Reported by	Covered areas	Date of solution	Type of solution	Legal/ other	Transferability
RAL Window and Front Door Installation Guideline	Germany	Fraunhofer IBP	Window installation, airtightness, water tightness, thermal bridges at window/wall connection	Since 1998, regular updates	Guideline and education of workers	Accepted rules of technology	Yes
RAL Certification of Window Installation	Germany	Fraunhofer IBP	Window installation, airtightness, water tightness, thermal bridges at window/wall connection	Since 1998	Certification of manufacturer including installation	Voluntary	Yes
German contractor's declaration	Germany	Fraunhofer IBP	Insulation of building envelope components, windows, heating and ventilation systems	Since 2009	Self-declaration by contractors	Obligatory	Yes
Guidelines for dwelling designers, builders, owners	Estonia	Tallinn University of Technology	Technical details, insulation layers, airtightness material, joints	2010-2012	Guideline	Voluntary	Yes
BUILD UP Skills QualiShell project	Romania	URBAN-INCERC	Knowledge/training, qualification of workers, building envelope (opaque and transparent) - focused on transmission characteristics and airtightness of the envelope	2013-2015	Qualification schemes, mechanism for long lasting large scale implementation	Integrated in the national qualification system	Partially
Swedish guidelines on waterproof layers in wet areas (GVK, BBV)	Sweden	Chalmers University of Technology	Waterproof layers in wet areas	Since 1988	Education of workers, guidelines and authorisation of companies	Voluntary, several insurance companies require work according GVK/BBV	Yes. Negotiations with insurance companies
Quality framework for ducts	Sweden	Chalmers University of Technology	Air duct tightness	Since 1966	Airtightness test and certification	Voluntary, but applied in 90-95 % of buildings	Yes

Table 4 (cont.): Overview of collected best practice examples regarding quality assurance on construction sites.

Solution	Country	Reported by	Covered areas	Date of solution	Type of solution	Legal/ other	Transferability
Guideline BuildE - Energy efficient	Sweden	Chalmers University of Technology	Communication between planners and contractors	Initiated in 2013	Checklist, guidelines, standardisation of calculation tools	Voluntary	Probably yes
Quality framework CIGA for insulation of cavity walls	UK	Fraunhofer IBP	Cavity wall insulation	Since 1995	Certificate for installers, guarantee for homeowners	Voluntary	In general yes. Connection to the UK ministries.
Quality framework SWIGA for insulation of solid walls	UK	Fraunhofer IBP	Solid wall insulation	2010?	Certificate for installers, guarantee for homeowners	Voluntary	In general yes. Connection to the UK ministries.
Guideline for selecting cool roofs	US/ Greece	University of Athens	Cool roofs	2010	Guideline	Voluntary	Countries /regions with hot climate and limited roof insulation

Table 4 (cont.): Overview of collected best practice examples regarding quality assurance on construction sites.

AI Training and certification schemes for installers at AIT

Reported by: Susanne Geissler, OEGNB

Covered areas: Installation of PV systems, solar thermal systems, heat pumps and ventilation systems

Date of solution: Trainings and certification schemes have been developed from 2001:

- ✓ training on heat pumps since 2001, accredited since 2005;
- ✓ training on solar thermal systems since 2004, accredited since 2009;
- ✓ training on PV since 2006, accredited since 2009;
- ✓ training on ventilation since 2007, accreditation started in 2015.

Responsible actor: Accredited certification body: AIT - Austrian Institute of Technology
<http://www.ait.ac.at/research-services/research-services-energy/training-education/?L=1>

Type of solution: Training and certification of workers

Summary: Trainings for HVAC installers and electricians, planners and other interested groups such as architects:

- ✓ Certified Solar Heating Installer and Planner
- ✓ Certified Solar Heating Practitioner
- ✓ Certified Photovoltaic Installer and Planner
- ✓ Certified Heat Pump Installer
- ✓ Comfort Ventilation Engineer

Some 2,500 participants have already successfully completed the training courses in order to gain direct access to the latest trends and technological innovations giving them a clear competitive edge in their industry. The comprehensive training programme is complemented by the option to obtain certification, which provides a visible sign of a strong commitment to quality and sustainability and creates additional competitive advantages.

Needed for certification according to EN ISO/IEC 17024 are:

- ✓ verification document of professional education;
- ✓ verification document of professional experience ;
- ✓ verification that the employer is a licensed enterprise (license needed to be able to work in the specific field);
- ✓ confirmation of course participation;
- ✓ examination document;
- ✓ data of reference projects.

The certificate is valid for three years, then re-certification has to be done. If there is no re-certification the certificate will be withdrawn. Certified persons are listed on the website of the certification body, see for example:

http://www.ait.ac.at/uploads/media/20140425_Liste_der_Zertifizierten_WP_Installateure.pdf

Trainings are offered in co-operation with organisations specialised on vocational trainings. The programme is part of “klimaaktiv” which is the Austrian Climate Protection Programme launched by the Federal Ministry in charge of reporting national CO₂-emissions. (<http://www.klimaaktiv.at/english.html>)

The following table shows an overview of the available trainings.

	PV system	Solar thermal	Heat pump	Ventilation
Prerequisites	First of all electricians and electrical engineers but also interested other planners and HVAC installers / planners, architects	First of all HVAC installers but also interested planners and architects	First of all HVAC installers and planners but also interested other planners and architects	First of all HVAC installers but also interested other planners and architects
Course duration	7 days (56 units) plus 1 additional day for examination	8 days (64 units) plus 1 additional day for examination	Module 1: 3 days (for planners) Module 2: 2 days (for practitioners) plus 1 additional day for examination	5 days (40 units) plus 1 additional day for examination
Cost of course (excl. VAT) [€]	1,400	1,400	Module 1: 840 Module 2: 560	1,450
Cost of examination (excl. VAT) [€]	200	200	120	200
Condition for certification	Pass exam and submit reference projects which are assessed and must be correct.	Pass exam and submit reference projects which are assessed and must be correct.	Pass exam and submit reference projects which are assessed and must be correct.	Certification has started in 2015. Pass exam and submit reference projects which are assessed and must be correct.

Table 5: Overview of the available trainings and certification of the Austrian workforce at the Austrian Institute of Technology.

Legally required or not: Voluntary. It is recommended in the sustainable building guidelines of the klimaaktiv programme to contract certified installers. The certification is however currently no

prerequisite for support programmes. Installers and their companies use the certificate as marketing instrument in order to stand out from competitors.

Impact: Until April 2015 AIT has certified or re-certified in total more than 540 installers (235 installers for heat pumps systems, 205 installers for solar thermal systems, 102 installers for PV and 2 installers for ventilation systems).

Transferability: Yes. AIT regards the scheme as transferable, but advises to adapt the scheme to national requirements and boundary conditions in other countries. They suggest to support the system by a general requirement for certification, for example in the RES Directive.

References: [1]

AI *Guidelines, checklists and commissioning protocols by professional associations in Austria*

Reported by: Susanne Geissler, OEGNB

Covered areas: Installation of PV systems, solar thermal systems, heat pumps and ventilation systems

Date of solution: Since ca. 2005

Responsible actors: Professional associations:

- ✓ solar thermal systems;
- ✓ ventilation systems;
- ✓ PV systems;
- ✓ heat pumps.

Federal Ministries:

- ✓ Federal Ministry of Transport, Innovation and Technology.
- ✓ Federal Ministry of Agriculture, Forestry, Environment, and Water.
- ✓ Federal Ministry of Science, Research and Economy.

Accredited certification body: AIT - Austrian Institute of Technology (<http://www.ait.ac.at/research-services/research-services-energy/training-education/?L=1>).

Type of solution: Guideline, checklist, commissioning protocol

Summary: Professional associations publish information material for better quality of the works and tools such as checklists for completion certificates and commissioning protocols:

1. Solar thermal systems: The association Austria Solar provides material at <http://www.solarwaerme.at/Profi-Center/Musterdokumente/>.
2. Ventilation systems: The association Verein Komfortlüftung/Verband Komfortlüftung provides material at: <http://www.komfortlüftung.at/proficenter> for single family houses, multi-unit residential buildings, schools and kindergartens.
These websites also list the certified installers having passed the examination of the respective course and undergone the certification procedure. As there is no certification scheme for ventilation yet, the website lists those installers having participated in the course and having passed the examination. Trainings are offered in co-operation with organisations specialised on vocational trainings.
3. PV systems: The association Photovoltaik Austria organises so-called practitioners' days for installers and electricians and other interested groups, approximately monthly and in different towns all over Austria. "Defects/failures during installation and how to avoid them" is one of the topics on the agenda. <http://www.pvaustria.at/pv-praktikertage/>.
Installation companies are listed on the website and the additional training they did; also, their certification (if available) is included in the description of the company. However, it is not possible to search for certified PV installers.
4. Heat pumps: The association Wärmepumpe Austria does not refer to quality of the works. The quality assurance measure described refers to the EHPA Gütesiegel für Wärmepumpen (EHPA quality seal for

heat pumps) introduced in 1998. <http://www.waermepumpe-austria.at/die-waermepumpe/qualitaetssicherung.html>.

In addition to the associations presented above the Federal Ministry of Transport, Innovation and Technology, and the Federal Ministry of Agriculture, Forestry, Environment, and Water are engaged in the topic quality of the works as there is awareness that the completed building must comply with the projections to achieve actual progress in terms of energy performance and building quality in general. They provide the following voluntary sustainable building guidelines in the framework of the programmes Building of Tomorrow and klimaaktiv (code of practice), among others (developed 2009-2013):

- ✓ air-tight construction;
- ✓ insulation of pipes;
- ✓ heating;
- ✓ ventilation with heat recovery;
- ✓ solar thermal systems;
- ✓ heat pump;
- ✓ general quality requirements for technical building systems.

Among others, these guidelines provide checklists and forms for commissioning and strongly recommend contracting a certified installer to ensure the quality of the works. The guidelines are available at <http://www.klimaaktiv.at/publikationen/bauen-sanieren/qualitaetslinien.html>.

The new national energy efficiency law dating from 11th August 2014 requires the Austrian Government to come up with guidelines for sustainable renovation by end of 2015 which will become mandatory for the buildings owned and used by the federal ministries. The development of this mandatory guideline is the responsibility of the Austrian Federal Ministry of Science, Research and Economy.

Legally required or not: No legal requirement.

Impact: Evaluation is not available.

Transferability: Yes.

AIII *Voluntary building certification including measurements (TQB)*

Reported by: Susanne Geissler, OEGNB

Covered areas: Entire building: addresses quality regarding energy performance and beyond (energy efficiency, renewable energy, water, materials, green spaces, etc.)

Date of solution: Pilot phase in 2001, scheme in place since 2003

Responsible actors: The development of the TQB scheme was supported by the Federal Ministry of Transport, Innovation and Technology. Later, part of the comprehensive scheme has been taken up by the Federal Ministry of Agriculture, Forestry, Environment, and Water as part of the *klimaaktiv* programme (national climate protection initiative) in the form of a self-declaration scheme without any cost for the building owner. The TQB scheme has been operated by OEGNB and the predecessor organisation.

OEGNB is a non-governmental organisation, an association consisting of stakeholders in the area of construction, including the Austrian Energy Agency and the relevant associations of the Austrian Chamber of Commerce.

Klimaaktiv is operated by the Austrian Energy Agency.

Type of solution: Assessment by third party

Summary: The Austrian TQB system for building design, building assessment, and building certification has been developed in Austria since 1998 in close contact with the international initiative “Green Building Challenge” (GBC) in order to stimulate the construction of user friendly, environmentally friendly and cost efficient buildings on the Austrian market. Since 2001 the assessment system has been continuously improved and adapted to different building types.

TQB (Total Quality Building) was developed for quality management in the course of building design and construction: the system provides the information necessary for designing a high performance building at

the pre-design stage (“high quality” in terms of improved comfort as well as decrease in negative environmental impact, at affordable costs), and assesses the performance achieved in two steps; (1) prior to construction and (2) prior to handing over. Assessment prior to handing over will be based on the verification of measurements such as blower door test and thermal. Measurements are not mandatory but presentation of proof is rewarded with a substantial number of scores.

Cost of certification (OEGNB charges for contracting the assessor and for administration of issuing the certificate) depends on the building size:

- Calculation of fee for buildings with up to 1,000 m² gross floor area: m² gross floor area x 0.40 EUR (to be paid two times, once for design stage and once for completion stage)
- Calculation of fee for buildings with 1,000 to 10,000 m² gross floor area: 400 EUR + (m² gross floor area - 1,000) x 0.30 Euro (to be paid two times, once for design stage and once for completion stage)
- Calculation of fee for buildings with 10,000 to 25,000 m² gross floor area: 3,100 EUR + (m² gross floor area - 10,000) x 0.20 Euro (to be paid two times, once for design stage and once for completion stage)
- Calculation of fee for buildings beyond 25,000 m² gross floor area: 6,100 EUR (to be paid two times, once for design stage and once for completion stage)

It is important to note that cost of measurements and other documents to verify building performance, to be submitted for certification, is not included. The building owner or the designated party is responsible for contracting experts producing the verification documents.

Another relevant scheme is the Passivhaus Certification scheme which is in fact a module of the voluntary sustainable building assessment scheme.

Legally required or not: No legal requirement. TQB certification is not part of a standard subsidy scheme. However, buildings owners of projects applying for funding in the framework of the funding programs of the Austrian Ministry of Transport, Innovation, and Technology must register for TQB-certification and undergo the procedure. There is an annual award celebration during the Vienna Congress on Sustainable Building (<http://www.bauz.at/en>) where building owners and design teams receive the certificates during a celebratory event.

Impact: During the past years, about 150 buildings have been certified. This number might seem low, considering the long operation time of the certification system. However, it is stressed that developers use the system internally to improve their quality assurance schemes without registering buildings for certification, and that training institutions use it for education. Therefore, there is considerable impact on the market. The main reason for low demand for certification is that the real estate sector does not demand for it because potential buyers and tenants do not demand for it, either.

Transferability: Yes. A suitable organization has to take responsibility of running the certification program. However, without strong motivation or incentives for the building owners the market for certification is probably limited and therefore it might be economically difficult to rely exclusively on the income from certification.

References: [26]

BI *Belgian approach to take thermal bridging into account in the EPBD-regulation, and to stimulate the building industry to improve thermal detailing [New Example]*

Reported by: Arnold Janssens, Ghent University

Covered areas: Thermal bridges: lack of technical details, joints not realised according to requirements/design, joints between window and walls not insulated, language barriers

Date of solution: since 2011

Responsible actors: Belgian regional authorities, industry, Odisee University College

Type of solution: guideline, legislation, education of workers

Summary: As the influence of thermal bridges occurring in the building envelope can be of major importance for the global energy performance of buildings, most European member states impose requirements on the heat losses through thermal bridges in their energy performance legislation. In the Belgian context nor the detailed analysis, nor a thermal bridge atlas was found to be a realistic approach to incorporate thermal bridge requirements in the EPBD-regulation. Instead a pragmatic approach has been developed in a collaboration between the different regional governments and research institutes KULeuven, UGent and BBRI, [34]. The methodology, introduced in the EPB-legislation in 2011, foresees three main options to take thermal bridges into account:

- the detailed calculation method based on linear thermal transmittance values,
- a pragmatic method based on simple basic rules and
- a penalisation method when no attention is paid to thermal bridges.

Mainly the pragmatic approach was well appreciated by the building industry, since it is based on simple rules which, when followed, do not require any calculation at all. Essentially, the basic rules guarantee a continuous insulation layer within the building envelope. The performance-based rules are defined in such a way that the requirements are relative to the insulation level of the building. Furthermore, their simplicity allows designers, contractors and inspectors to control, mainly in a visual manner, whether a details fulfils the requirements to be an EPB-accepted node. This way the pragmatic approach not only effectively accounts for the extra losses due to thermal bridges in the building envelope, it also increases the awareness of good thermal detailing in the building industry.

Apart from fulfilling one of the three basic rules a thermal bridge is also considered to be EPB-accepted if its thermal transmittance is smaller than a limit value (see figure 10). The limit value is depending on the geometry of the construction node. This allows for instance building industry to provide specific thermal bridge atlases that can be applied by designers without any further calculations. Several major building manufacturing companies have developed product documentation and reporting tools based on the EPB-methodology.

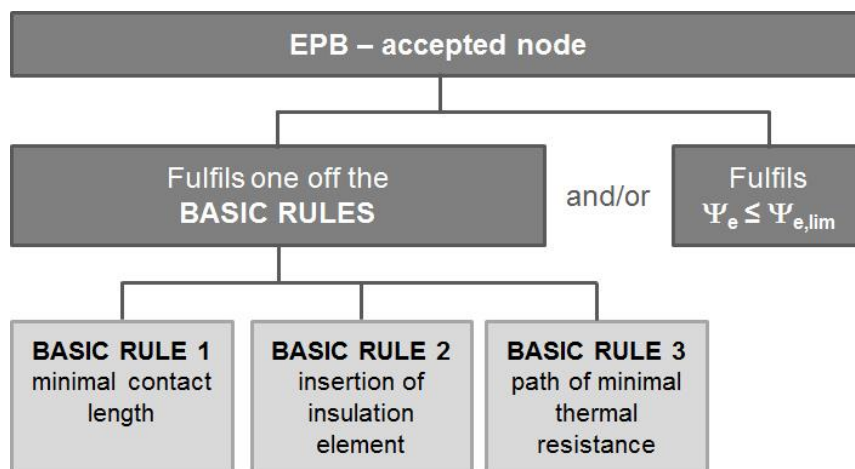


Figure 10: Possibilities for the assessment of EPB-accepted nodes (construction nodes with compliant thermal detailing)

Legally required or not: Regulatory/mandatory. The energy performance legislation requires the heat losses through building junctions to be taken into account according to one of three methods.

Impact: The requirements apply to all new residential and non-residential buildings, and have increased awareness of good thermal detailing in building industry and design. The effect is visible on construction sites: the use of specific solutions to avoid thermal bridges has increased (thermal breaks, continuity of thermal insulation). The requirements have also stimulated the development of more specific guidelines and tools by building industry.

Transferability: Yes. Similar guidelines and specific thermal bridge atlases already exist in other countries like Germany.

References: [9], [34]

Reported by: Marina Kyprianou Dracou, The Cyprus Institute

Covered areas: Insufficient knowledge/training, necessary specialists, wrong (insulation) material, installation of insulation, damages during construction, wet material, joints, roller shutters

Date of solution: Start in December 2013, 36 months of duration

Responsible actors: Cyprus Energy Agency, Cyprus Productivity Centre, Cyprus Organisation for Standardisation, Human Resource Development Authority of Cyprus, Cyprus Institute of Energy, Technical Chamber of Cyprus

Type of solution: Education/training

Summary: The WE-Qualify project has as its main objective to help the construction sector of Cyprus to overcome the barrier of lack of skills at the workforce and especially the lack of qualified personnel for the construction of energy efficient buildings. It shall develop three skills of technical training:

- ✓ skill 1: installation of thermal insulation;
- ✓ skill 2: installation of frames and external shading;
- ✓ skill 3: installation and maintenance of heating systems with biomass boiler.

During the project five pilot training programmes are expected to take place regarding the aforementioned three skills in order to evaluate the effectiveness of educational materials and to extract useful information for improving the project. During these programmes more than 125 people will be trained and education programmes and materials will be developed in order to be used by other training providers in Cyprus, as demonstrated by their interest to support the proposal.

The project develops appropriate educational materials and practical tools for technicians and trainers with an online platform with all the necessary technical information, giving equal weight to both theoretical and practical training of trainees. Also, three pilot training programmes for trainers and five pilot programmes for technical education (training people, and certification of individuals) will take place in order to evaluate the effectiveness of educational materials and to extract useful information for improving the project so as to be used by other training providers in Cyprus, resulting in better qualified workforce in the construction sector and achieving better quality of works in this sector.

Legally required or not: Recommended/voluntary

Impact: The impact of the implementation and results of this work, for installers, industry and society can be summarized as follows:

1. Promoting best practice energy efficiency of buildings and creating a more skilled workforce will help increase public confidence which will lead to the development of the construction market.
2. Improving the skills of workers will lead to more efficient construction and renovation of buildings, improve maintenance procedures and reduce maintenance costs.
3. Increasing the reliability of skilled workers will improve the quality of construction materials and renewable energy, which will reduce failures and increase consumer protection, therefore, will lead to a direct benefit for the industry.
4. Manufacturers and engineers will benefit from the existence of a skilled workforce.
5. The local community will benefit by increasing the energy efficiency of buildings and by the consequent reduction of energy consumption and greenhouse gas emissions from buildings and thereby improve the quality of life for the general public.

The solution, if applied on a national level, is expected to affect new buildings as well as the existing ones if they undergo a renovation regarding their insulation, doors and windows, external shading, and/or heating systems with biomass boiler.

The programme aims to:

- ✓ set the basis for the adoption of an acceptable national qualifications system, which sets high quality standards for the construction of energy efficient buildings;

- ✓ develop suitable and easily adaptable educational materials and tools that can provide effective support to the workforce and key stakeholders at national level;
- ✓ inform people on good practices and key parameters for efficient installations in buildings;
- ✓ create a group of skilled and trained workers to address those market needs in this area;
- ✓ encourage a greater number of workers to promote their professional skills; and
- ✓ inform the project-related groups (architects, engineers, land developers) and the general public about the specific qualifications system in order to create added value.

Transferability: In general yes.

References: [16]

CII *Scheme of Vocational Qualifications: I have the qualifications. I certify!, Cyprus*

Reported by: Marina Kyprianou Dracou, The Cyprus Institute

Covered areas: Insufficient knowledge/training, necessary specialists

Date of solution: Training for examiners, evaluators and evaluation of the examining centres took place in 2013 and the programme is now in use

Responsible actors: Human Resource Development Authority of Cyprus, European Union, European Social Fund, Republic of Cyprus, Structural Funds Organisation

Type of solution: Education and certification of workers

Summary: The aim of the scheme is the development of human resources through the knowledge and skills of the individual and the certification of professional qualifications. The scheme is implemented under the Operational Programme “Employment, Human Capital and Social Cohesion”.

One of eight economic sectors and professions that the scheme covers is the Building Industry, and for this sector it covers the following areas: construction/building works, construction of molds, carpentry, processing and application of steel concrete reinforcing, plumbing, electrical Installations, central heating systems, refrigeration and air conditioning systems, installation and maintenance of lifts, painting-decorative coatings, waterproofing systems, dry building, application of windows, raised floors, and project supervision. The professional qualifications for the areas mentioned above, are classified in five levels which take into account the level of required knowledge and skills, as well as the degree of responsibility involved in that level.

The scheme is aimed at men and women, workers, either employed or unemployed and economically inactive, who wish to be considered for certification of their qualifications in order to facilitate the job security or career prospects.

Examination of stakeholders is carried out in approved by HRDA’s examining centres monitoring the performance of work under real working conditions and/or accepted simulated conditions, by a two-member selection committee of examiners and one evaluator. This is followed by a short oral and written examination. The whole examination is conducted on the basis of Standards of Vocational Qualifications, which were prepared by specialists and finalized by technical committees.

Candidates may apply for examination and qualification regardless of how they acquired the necessary knowledge and skills. However, the certificate regarding the professional qualifications is awarded only to people who have dealt successfully in all the required areas of work and individual work in the field for which they have applied. If candidates succeed in fewer areas of work, then they are given certificate only for the specific areas in which they have succeeded. Therefore, the qualification certificates that are awarded to the successful candidates are a reliable and valid asset for careers.

It is important to mention that the participation, the examination and certification process for qualification, within the scope of the project is free for the people applying to be examined, as the programme is funded by the European Social Fund and the Human Resource Development Authority of Cyprus.

Legally required or not: Recommended/voluntary

Impact: The solution, if applied on a national level, is expected to improve the qualifications of the workforce and thus improve the quality of works in the construction sector. Through the examination and certification of qualifications participants are upgrading their knowledge and skills, making it easier to secure employment. Additionally, businesses that promote the certification of their employees, achieve the upgrading of human resources with the effect of increasing the productivity and competitiveness. Through the above, the scheme aims to improve the qualifications of the workforce and thus improve the quality of works in the construction sector.

Transferability: In general yes.

DI *German RAL Fenster- und Türen-Montageleitfaden [RAL Window and Front Door Installation Guideline]*

Reported by: Heike Erhorn-Kluttig, Fraunhofer Institute for Building Physics

Covered areas: Window installation, airtightness, water tightness, thermal bridges at window/wall connection

Date of solution: Since 1998; regular updates; newest edition from March 2014

Responsible actor: *RAL Gütegemeinschaft Fenster und Haustüren e.V.* [Quality assurance association of windows and front doors manufacturers] in cooperation with *ift Rosenheim* [Institute for Window Technologies, Rosenheim], *Bundesinnungsverband des Glaserhandwerks* [Association of the Glazing Trade], *TSD Tischler Schreiner Deutschland* [Association of Carpenters, Germany], *UBF Unabhängige Berater für Fassadentechnik* [Independent Organisation of Façade Technology Consultants], *VFF Verband Fenster + Fassade* [Association of Windows and Façade]

Type of solution: Guideline and education of workers

Summary: The *Gütegemeinschaft Fenster und Haustüren e.V.* is an association of manufacturers of windows, front doors, facades and winter gardens that have obliged themselves to ensure an outstanding product quality. In order to prove this quality the products are subject to a strict quality control. The qualified products receive the RAL-Gütezeichen, a quality certificate. In addition to that, the association publishes a guideline for installation of the high quality products. This guideline includes the accepted rules of technology for installing windows and front doors. A German language version can be purchased for 54 € at <http://www.window.de/473.html>. The guideline includes the following chapters:

- ✓ Principles of the joint formation
- ✓ Basics of building physics
- ✓ Fixation and sealing
- ✓ Planning and tender offers

Besides treating statics the part 'Fixation and sealing' deals mainly with the preparation of the components before the sealing, the different levels of sealing, the sealing functions, where to place the sealing system within the seam, the preferable seam size, different sealing systems, and presents exemplary installation technologies for different types of window systems and situations.

Legally required or not: As the guideline summarises the accepted rules of technology, which are referred to by the energy decree, it is an indirect approach of a legal requirement. Of course, the presented installation technologies are examples only. There might be other ways to correctly install windows. However, if damages occur that are connected with the installation of windows, the accepted rules of technology are taken as basis of the court decision whether the windows were correctly installed or not.

Impact: It can be assumed that the guideline is applied (or at least is thought to be applied) by all German window installers.

Transferability: Currently there is an approach to transfer the RAL guideline to Croatia where it was tested in a pilot project of a nearly zero-energy building documented within Concerted Action EPBD. The experiences made there showed that in Croatia training or at least more experience is needed to follow the guideline correctly.

References: [33]

DII German RAL Certification of Window Installation

Reported by: Heike Erhorn-Kluttig, Fraunhofer Institute for Building Physics

Covered areas: Window installation, airtightness, water tightness, thermal bridges at window/wall connection

Date of solution: Since 1998

Responsible actor: *RAL Gütegemeinschaft Fenster und Haustüren e.V.* [Quality assurance association of windows and front doors manufacturers] in cooperation with *ift Rosenheim* [Institute for Window Technologies, Rosenheim] as quality controller

Type of solution: Certification of producer including the installation

Summary: The *Gütegemeinschaft Fenster und Haustüren e.V.* is an association of manufacturers of windows, front doors, facades and winter gardens that have obliged themselves to ensure an outstanding product quality. In order to prove this quality the products are subject to a strict quality control. The qualified products receive the RAL-Gütezeichen, a quality certificate. Each manufacturer has to collect a standardised checklist of installation details for each window or door that they have produced, which has to be filled in and signed by the installer. Ift Rosenheim checks exemplarily that these checklists are available for each product that holds the RAL certificate.

Legally required or not: It is not a legal requirement, but a voluntary association of producers for outstanding quality. The producers have to ensure not only the high quality product, but also the correct installation by the window installers.

Impact: All German window and door manufacturers are members of the RAL Certification of Window Installation.

Transferability: The collection of a checklist for each product sounds rather sumptuous. However, the general approach can be transferred to other countries as well.

DIII German contractor's declaration [New Example]

Reported by: Heike Erhorn-Kluttig, Fraunhofer Institute for Building Physics

Covered areas: Building envelope components, windows, heating and ventilation systems

Date of solution: Since 2009

Responsible actor: Contractors of building renovation construction sites

Type of solution: Self declaration of compliance with minimum energy performance requirements

Summary: The contractor's declaration scheme supports the practical implementation of minimum energy performance requirements during the renovation of existing buildings. It increases the awareness of the minimum energy performance requirements on the part of two actors: the building owner and even more the contractor who executes the work on the construction site. By requesting a written confirmation about the performed work being in line with the energy performance requirements defined in the national energy decree, both actors will be reminded that they break the law if they do not meet the required qualities.

The strategy of requiring the contractor to confirm that the quality level realised on the construction site meets the requirements defined in the energy decree, only allows to use the contractor's declaration for the renovation of components and the extension of buildings. Here, the contractor is responsible for one or several components and the realised quality of the components can be easily compared to the required value(s) stipulated in the energy decree. The more complex approach of calculating a maximum primary energy use for new buildings can't be confirmed by a single contractor being for example responsible for the insulation of the walls or the installation of the windows. However, the building services system requirements also have to be confirmed separately in new buildings by using the contractor's declaration.

Legally required or not: § 26a of the German Energy Saving Ordinance “Energieeinsparverordnung (EnEV)” requires contractors performing the following work

- ✓ Modification of building envelope components (as further defined in Annex 3 of the EnEV)
- ✓ Insulation of ceilings to the attic (retrofit obligation as defined in § 10 of the EnEV)
- ✓ First installation or exchange of existing boilers or other heat generation systems (as defined in § 13 of the EnEV)
- ✓ First installation or exchange of existing heat distribution systems or hot water systems (as defined in § 14 of the EnEV)
- ✓ First installation or exchange of existing air-conditioning and ventilation systems (as defined in § 15 of the EnEV)

to confirm in writing to the building owner, right after completing the work, that the exchanged or implemented building or building services system components fulfil the requirements of the German Energy Saving Ordinance. The corresponding energy performance requirements are defined in §§ 8-9 and §§ 13-15 and Annex 3. They specify maximum thermal transmittance coefficients (U-values), minimum efficiencies for generation systems, minimum insulation levels for pipes, control strategies, maximum specific fan power, minimum heat recovery rates, etc.

§ 8 of the German Energy Saving Law contains fines for non-compliance with the specifications of the Energy Saving Ordinance. In case that a contractor does not issue a contractor’s declaration of the performed work or a building owner does not provide the requested declaration to the responsible authority a fine of up to 5.000,00 € applies.

In order to simplify the writing, the understanding and the control of the contractors’ declarations, various professional associations, but also most Federal States of Germany have developed templates for the different types of declarations.

Impact: It can be assumed that prior to the scheme some of the single-component renovation measures focused on the up-keeping of the building, but did not combine this with energy improvements as requested in the energy decree.

The German Energy Agency, dena, has conducted a study on the implementation of the Energy Saving Ordinance at the residential building stock in Germany, which includes an analysis of how many contractors are issuing the declaration in the regular building process. At the time of the study (2012) the ratio of issued contractors’ declarations was far from optimal. Only the window installers issued declarations in more than half of the analysed cases, followed by the roofers with slightly less than 50%. Since the contractor’s declaration scheme is an obligatory regulation there is clearly a need for further communication of the regulation. On the other hand roughly 40 to 50% of the construction work at the German residential building stock has resulted in a confirmed quality by the craftsmen companies. The same study has also analysed in general how many refurbishment measures have resulted in too low quality levels for measures at the building envelope and the building service systems. The percentage was rather low with 5-10% at most building envelope components and the heating system components and 10-15% for measures affecting the external walls (no or not enough insulation compared to the national requirements).

Transferability: The general approach of the contractor’s declaration has many advantages for the building owners, the state and the public and results in a few challenges for the contractors and the public authorities. The replication potential is rather high, because the simple approach can be used in all countries that have clearly structured minimum energy performance requirements that are related to one type of craftsmen mostly, e.g. maximum U-values or minimum boiler efficiencies etc. If the compliance of the minimum energy performance requirements involves several contractors (final energy requirements or primary energy requirements) the declaration has to be accompanied by detailed calculations and has to be signed by more than one contractor. This is against the nature of the scheme, as contractors would have to declare something for which they are not responsible. This approach should be covered by third party surveillance.

References: [11]

EI *Estonian guidelines for dwelling designers, builders, owners*

Reported by: Mikk Maivel, Tallinn University of Technology

Covered areas: Technical details, installation of insulation layers, airtightness material, joints (insulation, water tightness, airtightness)

Date of solution: 2010-2012

Responsible actors: Teet Tark, Targo Kalamees, EQUA OY

Type of solution: Guideline

Summary: During the period of 2010-2012 comprehensive guidelines were worked out how to plan, design and build low-energy detached houses. The guidelines include the most important data for building envelope elements, windows and building service systems like ventilation, heating, domestic hot water, etc. There are also good descriptions of the energy performance calculation procedure. The book is easy to read and its audience are not only the specialists. It has lots of simple illustrative pictures for different solutions for construction joints that help to minimize the thermal bridge impact.

Legally required or not: Voluntary

Impact: The guidelines can be downloaded without extra charge from the web. It is impossible to figure out detailed numbers, how many detached houses were built according to these guidelines. But everyday life shows that lots of detached-house builders and designers use it. The guidelines give valuable information about different technical solutions and their impact on the future energy consumption.

Transferability: Yes

References: [22]

FI *French Quali'Pac heat pump scheme [New Example]*

Reported by: Francois Durier, CETIAT

Covered areas: Heat pumps, technical details, installation of insulation layers on pipes; similar systems are available for solar thermal, PV, biomass boilers, geothermal cooling

Date of solution: 2007 - ongoing

Responsible actors: The solution was developed, launched and managed by the French Association for Heat Pumps (Association Française des Pompes à Chaleur - AFPAC) until 2009 and is managed since 2010 by the French organisation Qualit'EnR

Type of solution: Education of workers, qualification of companies and inspection by third party

Summary: French companies that install heat pumps can apply for the qualification scheme QualiPAC, in order to show to customers their skills for installing these appliances. The qualification is delivered for a period of 4 years (or 2 years for companies with a limited experience), with an annual control that the criteria for keeping the qualification are still fulfilled. The qualification criteria include technical skills (a technical expert within the company must have successfully completed an approved training) and some proven experience, the existence of relevant tools, a relevant insurance coverage and the engagement to follow a quality charter. Each qualified company is submitted to an audit during the first two years. The audit consists of looking at the actual quality of an installation. After 4 years, resubmitting for a new qualification requires to have been audited with an excellent or good result.

The qualification QualiPAC is accompanied by the mention RGE (Reconnu Garant de l'Environnement): this opens the right for customers to benefit from tax credits, zero-interest loans and white certificates (energy savings certificates).

Qualit'EnR has developed check-up files that help the installer to control the quality of his own work. A hot line is also available for technical advice. The journal "Qualit'EnR infos" regularly includes reminders about good practice, based on the failures that have been found during the audits.

There are similar schemes for solar thermal energy technologies (Quali'Sol), PV (Quali'Pv), biomass technologies (Quali'Bois) and geothermal cooling technologies (Quali'Forage).

Legally required or not: Voluntary. However the client must have an installation by a qualified company to have the possibility to get tax credits, zero-interest loans and white certificates (energy savings certificates).

Impact: In March 2015, there were about 3,300 companies having an active qualification. In the year 2014, 3851 persons have followed approved training sessions.

During the audit campaign 2014-2015, 374 installations have been audited. The results of these 374 audits of domestic heat pump installations show that:

- ✓ 81% of the audited installations have an excellent (44%) or good quality (37%),
- ✓ the quality is insufficient for 14% of the audited installations (orange),
- ✓ only 5% of the audits show a failing installation.

The most frequent minor failures were:

- ✓ Not enough information about the nature and quantity of the refrigerant
- ✓ No commissioning report available
- ✓ No thermal insulation for pipes and fittings in unheated spaces

The most frequent major failures were:

- ✓ No disconnecting devices between the water heating circuit and the domestic cold water circuit
- ✓ No study about heating needs

Transferability: Yes

References: [30], [31], [32]

RI *Romanian qualification scheme for construction workers to ensure high performance building envelopes (BUILD UP Skills QualiShell)*

Reported by: Horia Petran, The National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development (URBAN-INCERC).

Covered areas: All aspects related to building envelope (opaque and transparent) - focused on transmission characteristics and airtightness of the envelope

Date of solution: 2013-2015

Responsible actors: BUILD UP Skills QualiShell consortium (www.iee-robust/qualishell/en/), coordinator URBAN-INCERC

Type of solution: Qualification schemes

Summary: In the on-going process of implementing concerted and effective measures to achieve the 2020 targets, while the energy efficient building solutions and those for using renewables in buildings are often technically demanding, the need for ensuring appropriate training schemes for architects, engineers, energy auditors, craftsmen, technicians and installers (notably for those involved in refurbishment) is obvious. In this context, within the Pillar I of BUILD UP Skills initiative, a qualification roadmap to achieve the sustainable energy policy objectives for 2020 was developed, focusing on the blue collar workers. The BUILD UP Skills QualiShell project represents a natural continuation of BUILD UP Skills Romania (ROBUST) project and is addressing this need in order to support the development and implementation of two large scale and long lasting national qualification schemes for the installers of external thermal insulation composite systems and high efficiency windows/fenestration systems. The aim of the proposed approach is to ensure not only a high quality installation of very efficient building envelope components, but also the achievement of high performance building envelopes by developing effective tools to embed the adequate knowledge and skills in the relevant occupations and to foster the evolution in the national qualification system and in the vision of key stakeholders in the construction sector, moving towards the actual implementation of nearly zero energy buildings in Romania. Thus, the two schemes which are being developed together in the BUILD UP Skills QualiShell project could be seen as one big qualification scheme with two tailored components.

The qualification programs for the two occupations are defined under the National Qualification System with a course duration of 720 h (program finalised with the issue of recognised certificate of qualification), which may be reduced up to 360 h depending of the skills that the participants (trainees) have already acquired (this is checked by performing initial tests at the beginning of the training program). The estimated cost of such a training program is 500 to 600 EUR and should be supported by the trainee, the employer or by dedicated funding from ESF. To ensure an effective implementation of the developed qualification schemes the healthy development of training market is needed together with the definition of effective mechanisms and awareness actions for training suppliers, construction companies, technology suppliers and employees. One of the most effective way to ensure this is the definition of local partnerships between the education system and the construction sector, by bringing together the training supplier/vocational school, contractors and construction products producers in voluntary agreements to implement together training programs (based on natural drivers to match their respective needs and offers). Thus the costs incurred by the qualification programs could be realistically reduced by partial sharing of resources.

Legally required or not: Development under the National Qualification System, effective application depending on quality/performance requirements in the tendering process for increasing the energy performance of buildings. Currently the qualification certificate is not a pre-requisite for any official or voluntary project, e.g. certain funding programmes. However, the consultations organised within the National Qualification Platform and the dissemination activities strongly support the application of such requirements, starting from the building rehabilitation programs with public funding. This action should be implemented gradually, ensuring the existence of a sufficient number of qualified staff on the labour market and in first phase tender specifications for granting additional points to bidders with higher qualified staff should be promoted.

Impact: The major outputs of the ongoing action are summarised below:

- ✓ continuing the involvement of relevant stakeholders within the Romanian Qualification Platform, in a sustained consultation process to support implementation of BUILD UP Skills Romania Roadmap;
- ✓ detailed occupational analysis for clear definition of relevant competences for thermal insulators (ETICS installers) and insulation windows systems installers, together with the substantiation of flexible mechanisms to ensure continuous revision of the occupational framework;
- ✓ national qualification scheme for opaque building envelope insulation systems installers (ETICS installers) to ensure the need for qualified workers by 2020;
- ✓ national qualification scheme for window system fitters (installers of thermal insulation carpentry and efficient glazing) to ensure the need for qualified workers by 2020;
- ✓ effective mechanisms to ensure a large-scale and long lasting implementation of the qualification schemes, by use of existing networks, evaluation of competences acquired in non-formal and informal environments, and promotion of effective partnerships between education system and construction sector.

The action is still ongoing and the developed qualification schemes are to be tested within the implementation of two pilot courses for 30 trainees (the aim of the pilot courses is to test and validate the qualification scheme and not to do training *per se*), while several training supplier organisations are already under authorisation to implement qualification programs for the relevant occupations (using European Social Fund programs (ESF)). While the *installer of opaque building insulation systems* is a totally new occupation (recently introduced in the National Classification of Occupations and Qualification Registry), the *installer of insulating windows* is a revised occupation/qualification with newly defined competences and curriculum. It is estimated that at least 10 training providers will organise 3 courses per year with an average of 20 persons per class, which leads to 3,000 persons trained by 2020.

Transferability: The QualiShell approach is basically transferable to other countries and other technologies (trades in the construction sector), both at local/regional level or national level, depending on the applicable legal framework for education/qualification in each country. The main requirement for the application of QualiShell approach is the existence of a coherent qualification framework for the relevant trades in construction sector, which should contain a detailed definition of competences for each occupation and provide recognised certification documents for qualified persons.

References: [39]

SI Swedish guidelines on waterproof layers in wet areas

Reported by: Paula Wahlgren, Chalmers University of Technology

Covered areas: Waterproof layers in wet areas

Date of solution: GVK (*AB Svensk våtrumskontroll* [Swedish wet area control]) was formed in 1988, and BKR (*Bygggeramikrådet* [Council for building ceramic]) was formed in 1989.

Responsible actors:

1. GVK (*AB Svensk våtrumskontroll* [Swedish wet area control]) is an organisation that has developed the guidelines “*Säkra våtrum*” [“Secure wet areas”] and that gives authorisation to companies and workers to construct wet areas. The organisation GVK includes other organisations in the area of HVAC, flooring, insurance, building owners and tenant organisations.
2. BKR (*Bygggeramikrådet* [Council for building ceramic]) has developed the guidelines “*Bygggeramikrådets branscheregler för våtrum, BBV*,” [“Council for building ceramic branch rules”]. Companies and workers can also apply for BKR qualification.

There is also a project, the VASKA project, worth mentioning. The project started in 1987 and was financed by the Swedish research council Formas.

Type of solution: Education of workers, guidelines and authorisation of companies

Summary: GVK: The authorization requirements from GVK are applied both to the companies and the workers (fitter of waterproofing). When starting the work on a new wet area, there is a demand to report the work, the work has to be performed by authorized staff and company, and there is random control of the work. In order to become GVK authorized worker, you have to undertake a course arranged by GVK and to pass an exam. The work has to be performed according to the guidelines “*Säkra våtrum*” [“Secure wet areas”]. The guidelines include proper documentation of the work, demands on material and construction, demands on draining gutter, and application method/performance of waterproof membrane.

BKR: BKR is an organisation with focus on ceramic materials used in wet and dry areas. Their work is similar to that of GVK; they provide education that lead to competent (duly qualified workers) and companies, they develop guidelines (BVK), and there is random control of work. In order to obtain authorization according to GVK or qualification according to BKR, there are also other demands on the company, for example financial demands or no previous bankruptcy.

VASKA: In the VASKA project, guidelines and checklists were created that aimed at decreasing moisture damage in buildings. This also included checklists for waterproof layers in wet areas.

Legally required or not: Voluntary. However, several insurance companies demand that the wet area has been made according to GVK or BBV.

Impact: Approximately 400 companies are duly qualified according BKR and approximately 700 companies are authorized by GVK. There are demands from many insurance companies to make wet areas according to GVK or BKR. Since 1987 more than 4000 apartments were built according to the guidelines of VASKA, and in the year 2000 no apartment has had any water damage. (Statistically, there should be approximately 30 damaged apartments).

Less problems in wet areas, through the organisations knowledge on new solutions and research is spread. The BKR guidelines (BBV) were revised in March 2014 and GVK guidelines (“*Säkra våtrum*”) in 2011. Water damage cost more for insurance companies than housebreaking and fire together; therefore the impact of the Vaska-project is very positive when used.

Transferability: Yes. The link to the insurance companies is interesting for other countries as well.

References: [3]

SII *Swedish quality framework for ducts: Air tightness specification and verification according to AMA (General material and workmanship specifications).*

Reported by: Jan-Olof Dalenbäck, Chalmers University of Technology

Covered areas: Air duct tightness

Date of solution: Since 1966

Responsible actor: Specified in tenders, applied by contractor. AMA is published by Svensk Byggtjänst (the Swedish Building Centre) since 1976.

Type of solution: Airtightness test and certification

Summary: Air tightness specification and verification according to AMA. The duct air tightness is specified to meet a certain air tightness class, which means that there is a permissible air leakage to be met, and if required verified according to a given test procedure (measurements of allowed air leakage at a specified static pressure) specified in AMA. The contract is not approved unless the contractor can state, or if required, prove that the requirements are met. The builder can ask for a compliance test for a part of the ventilation duct work and the contractor has to prove the air tightness according to a given test procedure described in AMA.

Information in Swedish available at www.byggtjanst.se.

Legally required or not: Voluntary scheme applied in 90-95% of all contracted works

Impact: Air duct tightness according to specifications in the majority of all building projects. It covers 90-95 % of all contracted works, with no extra cost and no extra time as it in principle is the standard in all contracted works.

Transferability: Yes.

References: [2]

SIII *Swedish guideline ByggaE [BuildE – Energy efficient]*

Reported by: Pär Johansson, Chalmers University of Technology

Covered areas: Bad communication between planners and contractors

Date of solution: Initiated in 2013

Responsible actor: SP Technical Research Institute of Sweden

Type of solution: Checklist, guidelines, standardisation of calculation tools

Summary: The buildings of today are more optimized and complicated than before. Therefore, they are more sensitive to errors and problems such as built in moisture and air leakages. Buildings with high demands on energy efficiency tend to require technical solutions that may influence other aspects of the building's performance. A clear definition of functional demands and a quality assured building process leads to good conditions for the sustainable construction of an energy efficient building with good indoor environment. ByggaE [BuildE - Energy efficient] is not designed to be a quality assurance programme ready to be used in individual building projects, but is designed to be used as a guide to establish quality routines and control points. ByggaE should be used together with ByggaF (moisture control) and ByggaL (air tightness).

Information in Swedish available at www.byggae.se.

Legally required or not: No

Impact: The scheme is under development. There is a need in the industry for a standardised process and ByggaE could be that common process. More education and motivation for using the scheme is needed. The scheme may be connected closer to the work done within SVEBY (Standardise and verify the energy performance in buildings). Continued development with case studies of the model is needed to streamline the scheme in order to make it easier to implement throughout the building process.

Transferability: To be checked.

References: [14]

Reported by: Heike Erhorn-Kluttig, Fraunhofer Institute for Building Physics

Text taken from the website of CIGA (<http://www.ciga.co.uk>) and presentations of the scheme

Covered areas: Cavity insulation

Date of solution: Since 1995

Responsible actor: Solid Wall Insulation Guarantee Agency

Type of solution: Certificate for installers, guarantee for home owners

Summary: The Cavity Insulation Guarantee Agency is an independent body that provides 25 year guarantees for cavity wall insulation fitted by registered installers in the UK and Channel islands. The standard guarantee covers traditionally constructed residential property, although a CIGA commercial guarantee is also available to owners of qualifying non-residential property.

According to CIGA, the UK Government regards cavity wall insulation as the most effective energy savings measure that most people can carry out on their homes and a major contributor to reducing emissions of carbon dioxide, the main greenhouse gas. The Cavity Insulation Guarantee Agency was established in 1995 after consultation with the Government's Energy, Environment and Waste Directorate (a division of DETR) to provide householders with an independent, uniform and dependable guarantee covering defects in materials and workmanship. CIGA also operates and administers the Cavity Wall Insulation Self Certification scheme (CWISC) in association with the British Board of Agrément.

The scheme provides home owners with the comfort of knowing that work by registered contractors complies with the requirements of the Building regulations. Further details and a list of CIGA members who are also registered under CWISC are available on the dedicated CWISC website.

Before installation begins, a CIGA registered installer will carry out a pre-installation assessment to ensure that the property is suitable for cavity wall insulation. The installation of the insulation will then be completed at a mutually convenient time according to stringent technical standards laid down by CIGA. Once the work is finished and final payment has been received the installer will apply to CIGA for a guarantee, and a certificate will be sent directly to the building owner. The guarantee should be kept safely, as it may need to be produced in the event of a claim or if the property is sold, since the guarantee is also available to subsequent owners of the property.

The CIGA guarantee covers defects in materials or workmanship, and in the event of a problem CIGA's technical department is there to help. If the work is completed in England and Wales by an installer registered under the CWISC competent persons scheme then the certificate also incorporates evidence of compliance with the Building Regulations.

Since 2013 CIGA offers also a specific "hard to treat" cavity insulation guarantee (CIGA HTT Guarantee) for homes of more than 3 storey or walls with narrow cavities or homes that require substantial remedial work or specialised techniques.

Legally required or not: Voluntary. CIGA scheme and CIGA or equivalent guarantee is a requirement of all schemes and grants.

Impact: Cavity walls were introduced in the UK at about 1900 to help prevent water penetration and became the predominant construction type by ca. 1930. Built-in insulation in these cavities started in 1980 and by 2002 almost all new buildings were insulated. Consequently around 10 million buildings in the UK were built with unfilled cavities. Currently about 500,000 to 600,000 cavity wall insulations are realised as retrofits per year. This means about 2,000 installations taking place every day. Around 97% of all retrofitted cavity wall insulation installations are covered under the CIGA scheme. Over 5 million UK homes, or 1 in 5, now have the comfort of a CIGA Guarantee.

The CIGA HTT Guarantee has been used by nearly 130,000 home owners within the year 2013 (as confirmed by the Department of Energy & Climate Change).

Transferability: In general yes. Interesting is the connection to the UK ministries and the support schemes. CIGA points out that the key factors for the success of such a scheme are appropriate government policies to create demand and provide correct signals, robust consumer protection

arrangement and an industry willing to be proactive and to invest and implement best practice. A similar system exists in Belgium that has benefitted during the start phase from the UK experiences.

UKII *UK quality framework SWIGA for insulation of solid walls*

Reported by: Heike Erhorn-Kluttig, Fraunhofer Institute for Building Physics

Text taken from the website of SWIGA (<http://www.swiga.co.uk>)

Covered areas: Solid wall insulation

Date of solution: 2010

Responsible actor: Solid Wall Insulation Guarantee Agency

Type of solution: Certificate for installers, guarantee for home owners

Summary: SWIGA is the Solid Wall Insulation Guarantee Agency. It was established to provide householders with an independent, uniform and dependable guarantee covering professionally installed external, internal or hybrid (where both are used on the same property) solid wall insulation solutions. The SWIGA Quality Framework and Guarantee provides peace of mind for home owners and access to technical expertise in the event of any defect arising in the design, workmanship or materials and is aligned to the Green Deal & Energy Company Obligation (ECO) requirements for a 25 year guarantee.

The SWIGA quality framework ensures that all stages of the work, from survey to design and installation are carried out by competent companies using skilled operatives and that it is guaranteed to meet both the stringent high standards of quality and the requirements of an independent third party surveillance scheme. The guarantee is only available for work completed by registered SWIGA installers who install system certificate holders solid wall insulation systems.

The guarantee currently costs between 79 and 237 £ plus VAT depending on the building size and can be applied by private householders, private landlords, social housing landlords, green deal providers and energy companies. Once the work is finished and payment has been received, the installer member will apply to SWIGA for the guarantee. The certificate will be sent directly to the home owner and should be kept in a safe place, as it may be needed to be produced in the event of a claim or if the property is sold.

Legally required or not: Voluntary

Impact: The number of issued SWIGA guarantees couldn't be found out. By July 2013 SWIGA had over 100 installer companies that applied for membership.

Transferability: In general yes. Interesting is the connection to the UK ministries.

US-GI *Guideline for selecting cool roofs*

Reported by: Theoni Karlessi, Chrysanthi Efthymiou, University of Athens

Covered areas: Cool roof installation

Date of solution: 2010

Responsible actors: Bryan Urban and Kurt Roth (authors of the guideline), Fraunhofer Centre for Sustainable Energy Systems for the U.S. Department of Energy Building Technologies Programme and Oak Ridge National Laboratory under contract DE-AC05-00OR22725.

Type of solution: Guideline

Summary: The guidebook has been created to help building owners, but also installers, understand how cool roofs work, what kinds of cool roof options are available, and how to determine if cool roofing is appropriate for a building. Cool roof products exist for virtually every kind of roof. The decision to make an existing roof a cool roof usually means deciding to coat the roof, replace the roof, or build another roof on top of the existing roof. If the roof is in good condition; has relatively few, easy-to-repair leaks; and has at least five years of expected service life, a cool coating may be a good option. Note that the main reason for coating a roof is to extend its service life, and the energy savings alone will not normally

provide sufficient financial reason to coat a roof to make it cool. If the roof is in poor condition, or is approaching the end of its service life, a roof re-covering (adding a new membrane) or replacement (removal of the existing roof, and installation of a new one) is the likely option. Roof re-covering or replacement gives the opportunity to select any kind of roofing system and cool roof option. A durable roof is the result of the combined efforts of the building owner, designer, manufacturer, and contractor. Installers have to follow all manufacturer installation procedures. Proper installation is important to the long-term success of a cool roof project. For example, when applied properly, many cool roof coatings have been shown to last more than 20 years. When applied poorly, cool roof coatings can peel or flake off the roof within a couple of years. To ensure good product performance, building owners can seek appropriate warranties for both the product and the installation service.

Serious roofing problems should always be referred to a qualified roofer for repair before attempting any coating. Coatings cannot save worn-out, dried-out, or structurally weak roofs. Dry, sunny weather is ideal for the application in contrast to very cold nights when dew and frost can be a problem. It is crucial not to coat roofs that may have moisture trapped below the surface, but always allow each coat to cure before applying the next coat.

The steps included in the guideline are the following:

- ✓ thorough cleaning of the roof surface;
- ✓ repair and sealing of roof penetrations, tears, open seams, etc.;
- ✓ caulking and reinforcement of open seams, roof penetrations, cracks and tears;
- ✓ application of fabric to build flashings around roof edges or roof penetrations;
- ✓ if the roof has stucco parapets, examination for cracks along the sides and top;
- ✓ application of coating when the roof is dry and the sealant has set
- ✓ application of the top coat;
- ✓ additional coatings for scupper and ponding areas;
- ✓ inspection of the roof to note changes several times per year;
- ✓ occasional cleaning (washing) of the roof.

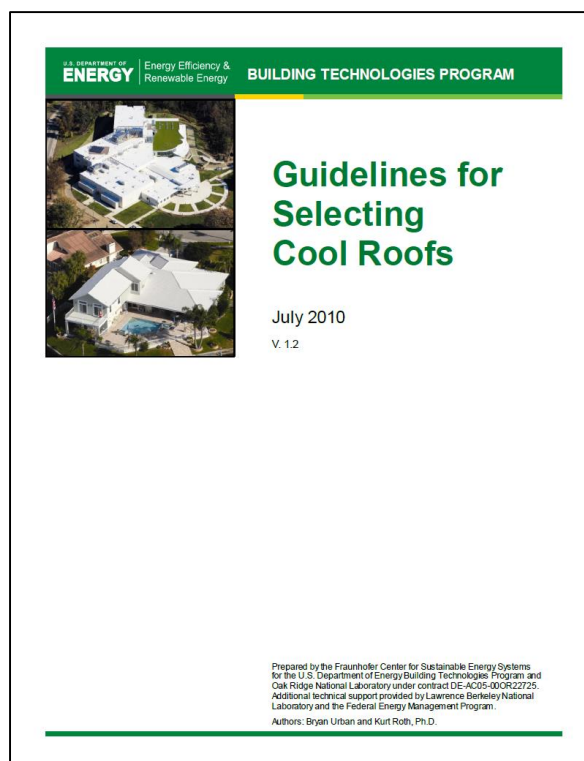


Figure 10: Title page of the Cool Roof Guideline developed by Bryan Urban and Kurt Roth of the Fraunhofer Centre for Sustainable Energy Systems. (Copyright: US Department of Energy).

Legally required or not: Voluntary

Impact: Cool roofs can reduce energy bills by decreasing air conditioning needs, improve indoor thermal comfort for spaces that are not air conditioned, and decrease roof operating temperature, which may

extend roof service life. In many cases, cool roofs cost about the same as non-cool alternatives. Weather has a definite impact on the types of cool roof systems that can be applied to a low-slope commercial roof. Single-ply cool roof membranes are weather-friendly systems which can be installed even with moisture in the air. Fluid coatings are more restricted in terms of application, however. If a contractor uses a cool roof product with a water-based technology or uses spray polyurethane foam, neither can be installed when rain is imminent, creating constraints on the contractor. In addition, some coatings use solvent carriers. There may be administrative constraints on the coatings which can or cannot be used based on the volatile organic compound (VOC) content.

The <http://elastek.com/how-to/apply-roof-coating/> website as well as the guidelines have been used by many associations and companies active in areas around the cool roofs.

Transferability: Countries/regions with hot climate and limited roof insulation.

References: [38]

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Annex: Clarification with respect to critical situations

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| 1. No or poor specifications of product performances: | If the designer team does not include the necessary specifications of the product performances in plans or details, but only in the tender text, misunderstandings are pre-assigned. Though the problem is created on the planning side the critical situation was included showing a link to the QUALICHeCK work package “Reliable and easily accessible input data”. |
| 2. No or poor specifications of execution performances: | A clear indication of execution performances (like for example the expected airtightness factor) pointed out in the tender text, but also additionally in meetings with the contractor is helpful for the contractor to understand the significance of energy related performance factors. Though the problem is created on the planning side the critical situation was included showing a link to the QUALICHeCK work package “Reliable and easily accessible input data”. |
| 3. No framework for control of performances: | A detailed framework for control, such as for example an obligatory airtightness test at the end of the construction phase, results in increased focus on the quality of the related work. The control can also be specific for a certain construction site, but should be pointed out in the tender and meetings with the contractor. |
| 4. Time pressure: | Time pressure, caused by worker’s delay or false time schedules on the planning side, is often the reason for an incorrect execution. There is not enough time to recruit an expert for each problem and the consequences of a solution had not been thought through. |
| 5. Language barriers at construction sites: | Language barriers are still a big problem in the building process, especially on-site. A lot of workers are not able to speak the national language or English as the world language. This causes problems like misunderstanding of construction details at inspections of the construction manager. Components can be incorrectly installed and at the end it’s a time- and money consuming undertaking. |
| 6. Insufficient knowledge of new technologies/construction workers not adequately trained: | Tightened national energy performance requirements lead to increased use of new technologies in different fields like renewable energy, for example photovoltaic systems. It is important to store and install these components very carefully. Construction workers should be regularly trained to avoid defects at new technologies. |
| 7. Necessary specialists not part of the construction team: | Some technologies require specialist workers to install and connect them to controls, etc. If such specialists are not part of the construction team, the regular craftsmen might be unable to cope with the tasks and mistakes can be made. |
| 8. Poor communication between planners and contractors: | If the communication between the planners and the contractors is not sufficient and regular, misunderstandings and mistakes in the realisation can occur. Especially complicated planning details should be discussed and questions that come up on the construction site should be quickly answered. |
| 9. Lack of technical details (improvisation on construction site): | Sometimes the planning process falls behind the realisation on the construction site. In this case, but also if there are simply not enough technical detail drawings available, the workers have to improvise on the site in order to ensure the construction progress. This may lead to incorrectly realised technical details. |
| 10. Constructed building components/ technologies not documented as a basis for subsequent maintenance: | As described under 6., sometimes the decision about how to install components and technologies is made at the construction site. If the components and technologies need maintenance work, the exact installation and settings, etc. should be documented to prevent problems/higher costs during maintenance. |

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| 11. Wrong (insulation) material: λ -value, thickness, etc.: | Wrong insulation material, either because it is not defined in detail on the plans or because the correct material is not available at the time on the site and thus replaced by “similar” material by the workers can lead to higher transmission losses, problems with joints, but also regarding safety (fire, mould, etc.). |
| 12. Incomplete or incorrectly installed insulation layer: gaps, uneven surfaces: | The workmanship of the insulation layer is also important for possible heat losses due to gaps in the insulation layer or uneven surfaces that might end up in not tightly installed insulation on walls. Moisture and mould can be resulting problems as well. |
| 13. Incompatible (insulation) material to specific situations: e.g. vacuum insulation | Some insulation material like for example vacuum insulation can’t be cut for adapting it to the required size on the site or for fixing downpipes. If a wall area is complicated to insulate, standard material has to replace the more advanced technologies. This decision should be made by the constructing team and the planner together so that the best replacement material is chosen. |
| 14. Damages of insulation material during construction: | The proper treatment of insulation materials on-site is important to avoid damages to the products. Cuts and dents will increase the transmission losses and can result in moisture problems. |
| 15. Wet (insulation) material: storage on site, protection during construction: | Insulation material or porous construction material has to be kept dry during storage at site and mounting at walls and roofs. Wet material can result in higher transmission losses and mould. |
| 16. Incorrect waterproof layers in wet areas (bathrooms, etc.) | Building components can get moist if waterproof layers in bathrooms, etc. are not correctly realised. They might be not completely laid-out or joints are not correctly realised. Additionally they might be included at the wrong position of the floor layers. In any case the result can be that major parts of the components get moist and can get rotten. |
| 17. Not enough drying time for built-in moisture (concrete, wood): | Construction material like concrete has to dry before building processes can continue. Otherwise the building can have mould problems. |
| 18. Wrong airtightness material: | If the airtightness layer and the adhesive are not compatible (not parts of the same system) joints will not be completely airtight or will not be durable airtight. Infiltration losses will thus be higher than expected. |
| 19. Incomplete air or moisture barrier: | If the air or moisture barrier sheets are not laid carefully with overlaps or system compatible glues, air leakages or moisture problems will occur. |
| 20. Damages of air or moisture barriers during the implementation: | Care has to be taken so that air or moisture barriers are not damaged by cuts, holes or similar on the construction site. Again, air leakages or moisture problems will be the result. |
| 21. Joints not realised with insulation according to requirements/design: | Solutions for joints on the construction site (for example roof/wall connections) sometimes differ from the planned situation, often because practical boundary conditions haven’t been foreseen correctly or even the detail hasn’t been designed by the architect. Here is a high danger that these realisations do not meet the thermal requirements and will cause higher transmission losses and maybe end in moisture/mould problems. |
| 22. Joints not watertight/airtight: | If joints are not correctly realised they might not be watertight or airtight. Problems with moisture or mould might be the result and higher infiltration losses. |

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| 23. Incorrectly realised joints due to installations: | Installations like pipes or ducts or electric cables that run through building components like roofs or walls are difficult to realise in an airtight or sometimes also water tight way. The reason is mostly that the component was completed before the installation was led through it. If this situation was not foreseen or even better timed in an optimised way before so that both types of workforces can cooperate solutions have to be found on the site. These are usually less than optimal regarding durability of the airtightness and water tightness. |
| 24. Wrong (insulation) material: water resistance | Insulation material in connection to the ground has to be water resistant. If regular material is used, it might rot and thermal losses are increased. |
| 25. Wrong (insulation) material: pressure resistance: | Insulation material under the base slab or foundations has to be pressure resistant. If the wrong material is used it will be damaged by the weight of the building and besides static problems also the thermal performance will be bad. |
| 26. Not enough space for ventilated roof: | Enough space between the back of the roof sheathing and the top of the insulation ensures a sufficient airflow for moisture removal. |
| 27. Not enough openings for ventilated roof: | If the openings for ventilation are insufficient the ventilation rate behind the sheathing won't be high enough to remove the moisture. |
| 28. Wrong coating for cool roof: | Glossy or white coatings increase the reflection of solar radiation and reduce the heat transfer into the buildings. If the coating differs from what was planned by the designers higher temperatures can lead to overheating in summer. |
| 29. Wrong windows or façade elements: U-value: | If windows or façade elements are used that do not meet the thermal criteria (U-values) as defined in the energy performance certificate, thermal losses will increase and the expected energy performance won't be met. The constructor needs to order the correct elements and should also check the elements when they arrive at the construction site. |
| 30. Wrong windows or façade elements: g-value, τ -value: | Also the solar gain value and the light transmission values of windows and façade elements have to be as defined in the planning. Higher solar gains can result in overheating, lower solar gains in higher heating energy use. Lower light transmittance values might lead to higher electricity consumption for lighting. |
| 31. Joints between windows and walls not insulated: | The correct installation of windows includes an overlap of the wall insulation material onto the window frame. If this overlap is missing a thermal bridge effect will occur and higher thermal losses and possibly moisture or mould problems will occur. |
| 32. Joints between windows and walls are not watertight/ airtight: | The connection between window frames and the wall has to be correctly sealed with durable sealing tapes, etc. to ensure water and airtightness. In some countries guidelines for windows and façade element installation exist. |
| 33. Top mounted roller shutters uninsulated at contact surface to wall: | Top mounted roller shutter systems mostly include no insulation at the area where the shutter box is put on top of the wall or at the cheeks of the box. The resulting thermal bridge increases the heat losses and can lead to moisture and mould problems. |
| 34. Blinds without sufficient rear ventilation: | If blinds are mounted without sufficient space between the façade and the blinds, the warm air behind the blinds can't be ventilated. Higher temperatures of the glazing occur and thus also higher radiation into the room and maybe unnecessary overheating of the building. |

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| 35. Wrong system components installed: collector peak load, inverter efficiency, fan efficiency, pump efficiency, etc.: | Wrong system components will lead to lower efficiency of the building service system. On the construction site the workers have to check whether the delivered components meet the requirements and sizing of the planning. |
| 36. Incorrect setting of hydraulic flows: | Higher hydraulic flows will lead to higher energy consumption and lower hydraulic flows to insufficient comfort (slower reaction of the radiator). |
| 37. No hydraulic calibration: | Hydraulic calibration is necessary to ensure stable hydraulic conditions in the pipework. Uneven heating distribution in the different connected rooms or zones are the result. In order to still secure the necessary heat at the weakest point of the pipework either the heat circulation pump increases the hydraulic head or the temperature of the heat circle is elevated. More energy is used for heating. |
| 38. Incompatible mounting material: anchors, etc.: | PV arrays, solar thermal panels, etc. should be mounted only with the fixations that belong to the respective systems. Otherwise damages of the arrays or panels, rust or fallen objects at high winds may occur. Similar care has to be taken with insulation material (anchors) and façades fixations. |
| 39. Wrong diameter of pipes/ducts: | The diameter of a pipe or duct influences the speed and the pressure of the water or air flow. For an energy efficient use of the heating, DHW or ventilation system the diameters should be installed as designed by the engineer. Too small ducts for example can result in too high velocity of air speed from air handling units and thus make people in the room feel uncomfortable because of draught. Also more fan energy is necessary and therefore more electricity. |
| 40. No/poor insulation of pipes or ducts: | If pipes or ducts are poorly insulated the heat distribution losses of the system will increase and the efficiency of the heating or ventilation system will decrease. Pipes or ducts should be insulated as required and planned, also taking into account any connections. |
| 41. No accessibility for cleaning of ventilation ducts or filters: | Maintaining and cleaning of ductwork plays an important role for a long-lived and well-functioning system. Residues can be removed and technical problems can be corrected. If the accessibility for cleaning is complicated less cleaning will be realised. |
| 42. Duct connections not airtight: | The different parts of the ducts have to be connected in an airtight way. Otherwise airflow losses and energy losses will appear. The airtightness of the duct system can be measured after construction. This quality control is mandatory in some countries. |
| 43. Joints with other ventilation system components not airtight: fan, AHU: | Similar to the connections between ducts, the joints with other ventilation system components like fans or air handling units (AHU) have to be airtight so that ventilation systems are energy efficient. |
| 44. Wrong settings: night setback, CO ₂ /humidity limits, temperature controls: | Controls of ventilation, heating, cooling and lighting systems need to be set according to design temperatures, times, CO ₂ -levels, humidity levels, etc. Those might be different from standard settings based on the user profile and the chosen components or desired energy level. Therefore the installers need to check carefully what the desired setting is and not simply follow a standard procedure for settings. Otherwise the systems might be either less energy efficient or less comfortable than planned. |
| 45. Damaged PV cells: | Workers have to take special care with sensitive products like PV cells during storing and mounting. Damaged cells will not work efficiently. |
| 46. Not enough rear | If PV cells are mounted too close to the roof, no or less rear ventilation is |

ventilation of PV arrays:	possible, the cell will get too hot and the efficiency will be significantly lower. The optimum distance to the roof and the corresponding fixture system should be realised as designed and defined in the product description.
47. PC cables: no mechanical protection	If the accessible wires are not protected against mechanical damages, the system may stop working.
48. PV cables: Mistakes regarding parallel vs. series connection:	One of the differences between the two connection types is that with parallel connection the efficiency of the PV system is better in case that parts of the arrays are shaded or have different orientations. The disadvantage of parallel connection is that more cables and more working effort are needed.
49. PV with no connection to inverter:	Reasons for a missing connection of PV modules with the inverter can be damaged cables or unconnected plugs. In this case the electricity produced will stay direct current and can thus not be fed into the electricity net.
50. Insulation behind the arrays not high temperature resistant:	Façade integrated PV systems should be insulated with high temperature resistant insulation material. Polystyrene or similar material could melt and thermal losses through the façade would increase.
51. Incorrect installation of PV system on the roof, causing water leakages:	Problems during the mounting of PV cells on the roof can cause water infiltration due to cuts or holes in the water barrier. Water can enter down to the insulation layer and moisture damages can be the result.
52. Incorrect installation of PV system on the roof causing damages of the roof/PV cells after storms:	In Belgium a severe thunderstorms caused many PV systems to break of partly or completely from the fixations. The cells, but also parts of the roofs have been damaged. PV arrays and other technical installations have to be fixed with special care.
53. Not enough distance/insulation behind solar thermal collectors at walls/roofs:	Solar thermal panels can reach rather high temperatures under solar radiation. If the rear side of the panels is in connection to the wall or roof without insulation in between the inner side of the building component will heat up as well and cause overheating problems.
54. Insulation behind the panels not high temperature resistant:	Roof integrated solar thermal panels should be insulated with high temperature resistant insulation material. Polystyrene or similar material could melt and thermal losses through the roof would increase.
55. Solar thermal feed in to storage at middle/top:	Solar heated water should be fed into storages at the low positioned feed-in. Otherwise the solar energy gains can't be used if the temperatures are not that high (low radiation or winter). At the top area of the storage the hottest water temperature exists.
56. Wrong type of antifreeze liquid in the solar thermal system:	The wrong type (or not indicated type) of antifreeze liquid can cause damages of the solar thermal collector or pipes as it can either be too aggressive for system components or not provide enough protection against freezing. It may for instance not cover very low temperatures in certain areas.
57. Safety valve of solar thermal system not fitted to container/ container not empty:	If no container is fitted to the valve the liquid running through the solar system will be lost in case there is an overpressure (mostly on hot summer days) and the valve opens. Replacement liquids can be rather expensive. If the container is not empty, the liquid can be collected and afterwards refilled into the system either.

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| 58. Heat pump setting:
no priority for DHW: | If combined heating systems do not include a priority for domestic hot water (DHW) demand, systems with limited capacity like heat pumps won't be able to provide DHW when required by the user. |
| 59. Heat pump feed in at middle/top: | Similar to solar thermal systems also heat pumps cannot always generate high temperature heating water, also because of their limited capacity. Thus the feed in of the heat pump should be at the low level of the storage so that the heat pump can feed in during longer times. |
| 60. Too low refrigerant quantity of the heat pump: | Refrigerant fluids have to be filled into the heat pump systems at the construction site. Heat pump installers have to take care that the quantity of the refrigerant is correct. Too low quantities will result in poor performance of the heat pump. |
| 61. Incorrect positioning of the heat pump outdoor unit: | If the heat pump outdoor unit (either the intake or the exhaust) is placed too close to walls or in an attic, the energy performance of the heat pump will decrease since not enough new air can be used by the heat exchanger. |
| 62. Time for defrosting of the outdoor heat exchanger set at a too low value: | Frosted heat exchangers have a bad performance. That's why the systems include a timer-dependend defrosting unit. If too short a time for this unit is set, the heat exchanger will not be completely defrosted and still have a bad performance. Also too long defrosting times can result in bad energy performance, simply because the system will use too much energy for heating up the heat exchanger. |
| 63. Incorrect flue gas exhaust at (wood) boiler | If the draught moderators on the flue gas exhaust of a boiler is not correctly installed toxic flue gas can get into the boiler room. |
| 64. Incorrect ventilation openings in (wood) boiler room | If there are not enough or not big enough ventilation openings in the boiler room, the air change rate is not high enough to prevent the air in the boiler room from becoming toxic. |
| 65. Wrong air flow rate of the ventilation system: | Air flow rates have to be set according to the design after the installation of the ventilation system in the building. If wrong air flow rates are set or if the default air flow rates of the system are simply kept, either the energy performance or the indoor air quality will be bad. |
| 66. Required filters of the ventilation system not included: | The filters in a ventilation system prevent the ductwork and other system parts from getting dirty. Dirty systems have a poor energy performance. Also the indoor air quality can be concerned. Installers have to make sure that the required filters are included. |
| 67. No electrical connection of the auxiliary heating of the ventilation system: | The auxiliary heating of a ventilation system provides a minimum temperature of the inlet air and therefore creates a better indoor comfort for the user. In case the auxiliary heating is based on electricity it can only work if the connection to the electricity grid hasn't been forgotten. |
| 68. Installation of a ventilation system without accessibility for maintenance: | Ventilation systems have to be inspected, maintained and cleaned at regular intervals. If the accessibility is limited, cleaning and maintenance will be more complicated. Poor indoor air quality and a deterioration in the energy performance will be the result. |
| 69. Noise due to ventilation unit position: | If the installer places the ventilation unit at a wrong position it will increase the noise of the system and reduce the user satisfaction and the maybe the running time. |
| 70. Wrong installation of ventilation system silencers: | Ventilation system silencers need to be properly installed on the air supply and air exhaust duct, otherwise the system will be too noisy and the user will be not satisfied with the ventilation system. |

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