

Appendix 3 a-e

Detailed PROST Purchase Specifications:

- 3a Fluorescent lamp specifications
- 3b Fluorescent lamp ballast specifications
- 3c Luminaire efficiency specifications
- 3d T5 System specifications
- 3e Window specifications

PPS1: PROST Fluorescent Tube Lamp Specifications

Specifications

Table 1. Purchase specifications for linear T5, T8 and T12 fluorescent tube lamps.

	Tube Nominal Power	Recommended Efficiency (According to EU Directive 98/11/EC defining Energy Label for household lamps)
T5	14W	Class A
	35W	Class A
T8	18W	Class A
	36W	Class A
	58W	Class A
T12		Replace where possible with T8

Additional Specifications

The specifications do not apply to T8 Fluorescent Tubes with a Colour Rendering Indexing greater than 90. Use fluorescent tubes with a Colour Rendering Indexing greater than 90 only when explicitly required by building codes since these tubes are roughly 30% less efficient than other recommended triphosphor tubes.

The EU Directive 98/11/EC was introduced in July 1999, and required cross country compliance by January 2001. In the case that products are not categorised according to the EU Directive 98/11/EC, purchase officers should refer to Table 2 and Table 3.

Table 2. Minimum efficiency requirements for T8 fluorescent tubes powered by standard electromagnetic ballasts, as usually reported in product catalogues.

	Tube Nominal Power	Colour Rendering Index (CRI)	Range of Efficiency (lumen/watt)	Recommended Efficiency (lumen/watt)
T8	18W	< 90	52-75	75
		> 90	55-58	55
	36W	< 90	65-93	93
		> 90	64-65	64

Table 3. Minimum efficiency requirements for T5 fluorescent tubes powered by electronic ballasts. The table reports the nominal luminous efficiency of T5 tubes at 35°C .

	Tube Nominal Power	Colour Rendering Index (CRI)	Range of Efficiency (lumen/watt)	Recommended Efficiency (lumen/watt)
T5	14W	80 < CRI < 90	89-96	96
	35W	80 < CRI < 90	97-104	104

Comments

Replacing standard Class B halophosphor with recommended Class A triphosphor tubes increases light output from luminaires by roughly 20% which :

- increases the possibility of using a limited number of tubes in multiple lamp luminaires
- decreases the probability that users will introduce additional portable light sources (for example desk lamps)

In refurbishing, using recommended triphosphor fluorescent tubes allows the total installed power to be reduced.

Example of Savings and Costs

Table 4. Example of Cost Effectiveness of using recommended triphosphor fluorescent tubes considered over the lifetime of the tubes (8,000 hours), used with standard electromagnetic ballasts

System Type	Tube Efficiency	Tube Efficiency	No. of Luminaires	Total Annual Energy Use	Total Lifetime Savings	Energy Use	Payback	Lifetime Savings
		(Lumen/W)		(kWh/year)	(Euro)	(kWh/year/m2)	(years)	(Euro/yr/m2)
4x18W	Standard	62	50	16,227		41		
	Recommended	75	41	13,414	313	34	0.67	0.78
2x36W	Standard	75	41	13,414		34		
	Recommended	93	33	10,818	391	27	0.28	0.98

Using recommended triphosphor fluorescent tubes, the same lighting levels are achieved using less luminaires which reduces system installed power and hence annual energy use.

The payback time considers the recovery of the extra cost of purchasing recommended triphosphor tubes rather than standard halophosphor tubes.

However choosing recommended triphosphor rather than standard halophosphor tubes in system refurbishment the financial benefits would be much greater than those reported in Table 4 since the reduction in the initial purchase cost of luminaires would outweigh the additional lamp costs.

Cost Effective Assumptions

Table 5.

Single Luminaire Power :	91 W	2*36 W T8 tubes + 19 W ballast or 4*18 W T8 tubes + 19 W ballast
Operating Hours	3600 hours	
Lamp Lifetime	8000 hours	with electromagnetic ballast
Space Lighting Level	300 lux	
Area illuminated	20m x 20m	ceiling height 2.7 m
Energy Price	0.1 Euro/kWh	
Discount Rate	8%	
Purchase Price of Recommended Triphosphor Tubes	3.47 Euro	For both 18W and 36W versions.
Purchase Price of Standard Halophosphor Tubes	1.92 Euro	For both 18W and 36W versions.

Considerations on Specified Efficiency Levels

The specifications identify minimum acceptable energy class for T5 and T8 linear fluorescent tubes based on the energy label for household lamps as defined in the Commission Directive 98/11/EC.

The directive came into force in July 1999, and required compliance after a transition period, by January 2001. However it is still possible to find product catalogues in member states and other sources which do not categorise products on the basis of the label. (For example the EU Green Light web site does not refer to the EU Energy Label for lamps)

Table 2 and Table 3 therefore identify approved products in terms of luminous efficiency. The tables are anyway useful in that they provide values which can assist in system design.

The specifications suggest the purchase of Class A fluorescent irrespective of the number of hours of use.

In existing systems the replacement of standard halophosphor with recommended triphosphor Class A tubes does not directly lead to a reduction in installed power of the plant and therefore any guaranteed reduction in energy use. Instead installing Class A tubes in existing systems:

- increases the possibility of using a limited number of tubes in multiple lamp luminaires.
- decreases the probability that users will introduce additional portable light sources (for example desk lamps)

However it is difficult to determine the reduction in running costs which would result from such “avoided use”, and therefore the cost effectiveness of introducing more efficient Class A lamps.

Certainly in situations in which it can be demonstrated that the introduction of Class A lamps would not result in any reduction in the accumulated hours of use of the lighting system then there would be no economic or energetic benefits to buying Class A lamps and therefore there might be an argument for choosing less efficient but cheaper halophosphor lamps.

However it must be remembered that though Class A recommended lamps are roughly 75% more expensive than halophosphor lamps, they last 33% longer (12.000 hours instead of 9.000 hours - this is not considered in the example of Savings and Costs above). Thus considered in terms of Euro per hour of lamp life, Class A lamps are actually only 36% more expensive than standard halophosphor type. If manpower costs for earlier replacement of standard halophosphor lamps were also to be considered it is probable that total costs of using Class A lamps would be comparable to the total costs of using halophosphor lamps.

Given that that Class A triphosphor lamps also provide better light quality (CRI > 80) than halophosphor lamps which increases space comfort levels (and worker productivity ?) and the fact that there is nevertheless a possibility of reducing system usage, the present document makes a general the specification to purchase Class A, irrespective of use.

When planning and installing new systems the use of Class A lamps allows the total number of luminaires to be reduced and hence the installed power. Since Class A lamps are roughly 20% more efficient than standard halophosphor lamps, systems using Class A tubes provide the same level of illumination using roughly a fifth less lamps.

In general the savings from purchasing less luminaires should outweigh the additional cost of purchasing more expensive recommended Class A tubes. Table 6 summarises total typical investment costs for illuminating a 20m x 20 m space to 300 lux, using recommended triphosphor Class A tubes and standard halophosphor tubes; the total investment costs of the efficient systems being from 13 to 19% less than the inefficient designs (depending on luminaire type).

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Table 6.

Tube Type	Luminaire Type	Lamp Efficiency (Lumen/W)	No. of Luminaires	Investment Cost		Total
				Tubes (Euro)	Luminaires (Euro)	
Standard	4x18	62	50	380	3.814	4.194
Recommended	4x18	75	41	569	3.153	3.722
Standard	2x36	75	41	157	3.153	3.310
Recommended	2x36	93	33	229	2.543	2.772

Similar results will be obtained in smaller spaces, i.e. total investment costs of using recommended triphosphor lamps will be less than using standard halophosphor lamps. Thus irrespective of the hours of use it proves costs effective to purchase Class A triphosphor lamps.

Obviously the lower installed power of a Class A triphosphor system compared to a standard halophosphor system delivers further savings as the plant is used. Figure 1 reports the accumulated costs of purchasing energy and lamps in the first two alternative systems listed in Table 6. After 12 000 hours of use (roughly 3 years under typical conditions) total savings amount to 890 Euro.

**Example of Accumulated Costs
of using Recommended
and Standard Fluorescent Lamps**

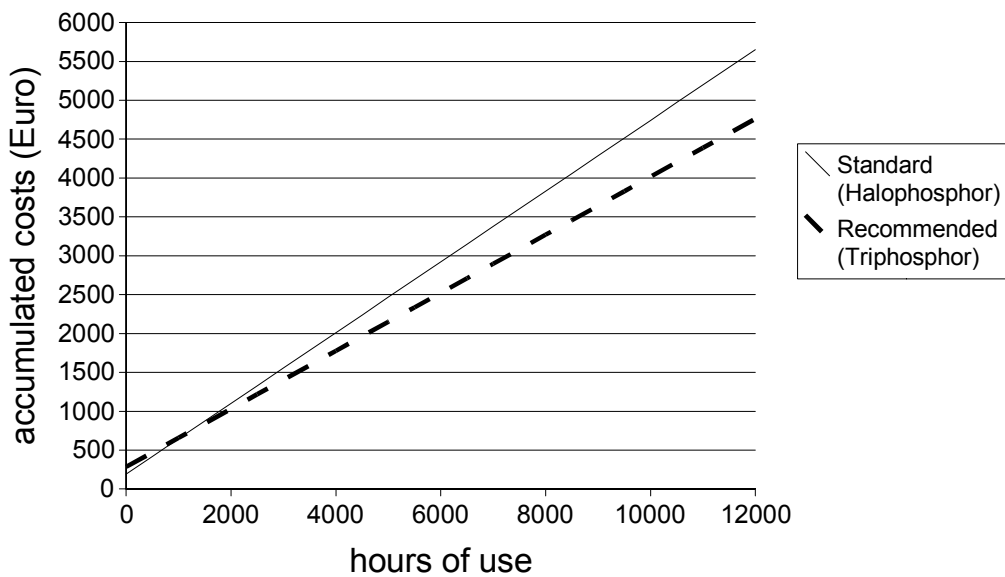


Figure 1. Accumulated costs of purchasing energy and lamps in a standard halophosphor system (50 4x18 W luminaires) and a recommended Class A triphosphor system (41 4x18 W luminaires). The analysis does not include the initial purchase costs of the luminaires in the two systems.

Existing National Purchase Specifications

Femp

Table 7 attempts to compare FEMP and PROST specifications for T8 and T12 fluorescent tubes, though direct comparison is not possible since the power rating for systems in Europe and the USA differ. In addition 8 foot tubes are not marketed in Europe.

The table follows in part the scheme set out in the FEMP recommendations. FEMP recommendations are made based on the total luminous flux of tubes. To allow comparison with the PROST specifications, the FEMP recommendations are translated into tube efficiency in terms of lumen/Watt.

Considering the different power ratings operated in the USA and Europe, and the difference in products marketed it only proves possible to compare specifications for four foot T8 tubes. For these models the PROST specifications equate with the “Best Available” level identified by FEMP which is slightly more restrictive than the FEMP “Recommended Level”.

Table 7. Comparison of FEMP and PROST purchase specifications for fluorescent tube lamps. Shaded cells highlight PROST specifications. Bold text highlights comparable FEMP and PROST specifications.

Lamp Type Diameter	Power (W)	FEMP				PROST
		Recommended		Best Available		Lumens/Watt
		Lumens	Lumens/Watt	Lumens	Lumens/Watt	
Two foot Lamps						
T8	18					75
Four foot Lamps						
T8	32	2800	87.5	3000	93.75	
T8	36					93
T12	34	2800		2900		
T12	40					Buy T8
Five foot lamps						
T8	58					88
Eight Foot Lamps						
T8	59	5700	96.61	5950	100.85	
T12	60	5600	93.33	6000	100	
U-Tube Lamps						
T8	31	5700		2850	91.94	
T12	34	5600		2760	81.18	

City of Frankfurt am Main

The lighting efficiency of lamps (including ballast) should be at least 50 lm/W (e.g., fluorescent lamps, CFLs).

Which is not directly comparable to PROST specifications which consider fluorescent tubes and ballast's separately.

However we make a limited comparison with the Frankfurt am Main specifications by determining total systems efficiency (ballast + lamp) when using PROST recommended fluorescent tubes in typical lamp configurations (2x18W and 2x36W). The calculations consider using fluorescent lamps with both CELMA Class D electromagnetic and CELMA Class A2 non dimmable electronic ballast's.

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Table 8. System efficiency of using PROST recommended Class A triphosphor fluorescent tubes with Celma Class D electromagnetic ballasts

	System Type	Colour Rendering Index (CRI)	Class A Output per Lamp (lumens)	System Power (Lamp + Ballast) (Watts)	System Efficiency (lumens/Watt)
T8	2x18W	< 90	1350	46	59
		> 90	1000	46	43
	2x36W	< 90	3350	91	74
		> 90	2350	91	52

Table 9. System efficiency of using PROST recommended Class A triphosphor fluorescent tubes with Celma Class A2 electronic ballasts

	System Type	Colour Rendering Index (CRI)	Class Lamp Output (lumens)	System Power (Lamp + Ballast) (Watts)	System Efficiency (lumens/Watt)
T5	2x14W	80 < CRI < 90	1350	30.5	89
	2x35W	80 < CRI < 90	3650	78	94
T8	2x18W	< 90	1350*	36	75
		> 90	1000*	36	56
	2x36W	< 90	3350*	71	94
		> 90	2350*	71	66

* Luminous flux of recommended triphosphor Class A. When used with electronic ballast's some manufacturers report a slight derating with respect to the reported value of around 4%.

Further Analysis

Table 8 and Table 9 list the complete set of linear fluorescent tubes currently marketed in Europe, of which the present document provides purchase specifications for the five most common types used in space lighting.

Future work might develop a LCC costs analysis for each of the remaining 19 lamp types. Alternatively a general specification can be made to purchase Class A fluorescent tubes, based on the reasonable assumption (based on the present calculations reported here) that this proves cost effective, leaving the onus on purchase agents to prove otherwise.

Table 10. Set of T5 tubes marketed in Europe. Shaded cells indicate tubes for which the present document provides purchase specifications.

Lamp Type	T5													
	16													
Diameter (mm)	136	212	288	517	549	849	549	1149	1149	849	1449	1149	1149	
Length (mm)														
Nominal Tube Power (W)	4	6	8	13	14	21	24	28	35	39	49	54	80	
Used in Standard Luminaires					x			x	x					

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Table 11. Set of T8 tubes marketed in Europe. Shaded cells indicate tubes for which the present document provides purchase specifications.

Lamp Type	T8											
Diameter (mm)	26											
Length (mm)	470	360	438	720	590	970	895	970	1200	1047	1500	
Nominal Tube Power (W)	10	14	15	16	18	23	30	36-1	36	38	58	
Used in Standard Luminaries					X				X			X

PPS2: PROST Ballast Specifications

Specifications

Table 1. Annual lamp usage at which CELMA Class B2 low loss and Class A2 electronic ballasts should be purchased for T8 fluorescent lamps.

System Type (W)	Number of Ballasts		Low Loss (Celma Class B2) from	to	Electronic (Celma Class A2) above
	Standard/Low Loss	Electronic	(hours/year)	(hours/year)	(hours/year)
2 x 18W	1	1			
4 x 18W	2	2			
1 x 36 W	1	1	600	1500	1500
2 x 36 W	2	1	-	-	700

Example of Savings and Costs

Table 2. Example of Cost Effectiveness of using Class A2 electronic ballasts.

		Electromagnetic	Electronic	
Luminaire Type		2x36	2x36	
Total System Power	(W)	92	70	
CELMA Class		D	A2	
Use	(hours/year)	3600	3600	
Total Annual Energy Use	(kWh/year)	331	252	
Discounted Ballast Price	(Euro)	4.8	20.0	
Energy Costs	(Euro/anno)	33	25	
Energy Savings	(Euro/anno)			7.92
Maintenance Savings	(Euro/anno)			1.12
Simple Payback	(Years)			2.23
NPV (ten years, 8%)	(Euro)			42
IRR (ten years)	(%)			81

Cost Effective Assumptions

Table 3.

Energy Price	0.1 Euro/kWh
Lifetime	10 years
Discount Rate	8%
Lamp Cost (T8 36W)	3.74 Euro
Lamp lifetime with electromagnetic ballast	8,000 hours
Lamp lifetime with electronic ballast	12,000 hours

A conservative estimate for the cost of the electronic ballast is used in the above example. Obviously a cheaper electronic ballast would lead to even greater lifetime financial savings than those reported in Table 2 (see next section for a discussion on the purchase price of electronic ballasts).

Considerations on Recommended Efficiency Levels

Ballast Purchase Price

The specifications identify the point at which the use of a low loss or electronic ballast becomes cost effective. As in all cases in which we aim to establish cost effectiveness, it is important to have reliable data on product purchase prices.

Unfortunately in the case of electronic ballast it proves relatively difficult, compared to some other technologies, to establish purchase prices, which vary notably and unexplainably between suppliers.

The present study considered the list price of products from 6 suppliers:

- one dedicated supplier of electronic ballasts (Supplier 1)
- three luminaire manufacturers which supply luminaires ready installed with electronic ballasts (as well as electromagnetic and low loss) (Suppliers 2, 3 and 4)
- two important lamp manufacturers (Suppliers 5 and 6)

Table 4 lists the average price practised by the 6 suppliers for their different Class A2 none dimmable ballasts. Generally each supplier provides at least two electronic ballast types (rapid start or pre-heat) for the different lamp combinations, though Supplier 1 (the specialist supplier) provides up-to four types.

However in developing the LCC analysis in most cases we base our analysis on the list price offered by the single dedicated ballast supplier (Supplier 1), rather than the average price of all suppliers.

The reasons for this are :

- ❖ Supplier 1 offers the most coherent prices.
 - Other suppliers practice incoherent prices in their own product lines, for example the same ballast varying by 30% depending on the luminaire in which it is sold.
 - Though list prices practised by other suppliers might be higher than list prices practised by Supplier 1 they vary significantly between supplier, indicating that there is no typical price.
- ❖ The last three points would indicate that:
 - list prices practised by Supplier 1 probably reflect the fact that Supplier 1 is a dedicated manufacturer of electronic ballasts, allowing economies of scale in fabrication and importantly, the marketing strategy of Supplier 1 is likely to be aimed at increasing sales of this single product.
 - for Suppliers 2 to 6 electronic ballasts would seem to serve as a marketing tool to assist the main business activity, namely the sales of luminaires or lamps. Thus for example as a means of accentuating the difference between low and high quality products lines. Also there are probably issues of existing supply contracts and stock of standard ballasts.
- ❖ Supplier 1 is nevertheless an important multinational offering guaranteed products.
- ❖ It is likely that prices would fall into the region of those practised by Supplier 1 should there be a sustained purchase of electronic ballasts by the Public Administration across Europe.

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Table 4. List price of electronic ballasts practised by 6 suppliers.

Ballast Type (W)	Source	Year	List Price		List Price for Analysis (Euro)	Comment
			Ballast (Euro)	Variation w.r.t. Elettromagnetic (Euro)		
2x18W	Supplier 2	2000		14.98	15	
	Supplier 1	1998	17.91	15.11		
	Supplier 3	2003		15.63		
	Supplier 4	1999		25.31		
	Supplier 5	2001	43.38	40.58		
	Supplier 6	1999	68.95	66.15		
1x36W	Supplier 1	1998	16.56	13.76	15	
	Supplier 3	2003		25.73		
	Supplier 2	2000		26.34		
	Supplier 5	2001	39.12	36.32		
	Supplier 6	1999	53.97	51.17		
2x36W	Supplier 1	2003	14	11.2	15	
	Supplier 1	1998	17.58	14.78		
	Supplier 3	2003		18.34		
	Supplier 3	2003		24.42		
	Supplier 2	2000		28.41		
	Supplier 5	2001	43.38	37.78		
	Supplier 6	1999	62.62	57.02		

The Specification

The specifications identify the operating hours at which Class B2 low loss and Class A2 electronic ballasts become economic, considering the accumulated costs (ballasts purchase cost, electricity acquisition and lamp replacement) of the different (electromagnetic, low loss and electronic) systems. The accumulated costs are shown graphically in Figure 1 and Figure 2.

The costs of wiring the different systems is not taken into consideration: Certainly when replacing an existing electromagnetic with an electronic ballast there will be a need to rewire the luminaire. However any additional cost of rewiring probably proves marginal compared to the cost of removing the luminaires and transporting to the workshop; necessary even if replacing with a standard electromagnetic ballast.

In any case we also choose to ignore the cost of a starters for standard electromagnetic systems (cost from 4 - 7 Euro), which would weigh against (probably outweigh ?) any additional wiring costs associated with electronic ballasts.

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Table 5. Values of parameters used in developing the PROST purchase specifications.

Material Cost

	Lamp Cost 18W, 36W (Euro)	Ballast Cost		
		Standard 2x18W, 1x36W (Euro)	Low Loss 2x18W, 1x36W (Euro)	Electronic 2x18W, 1x36W, 2x36W (Euro)
List Price	4.68	3	4	15
With Discount (20%)	3.74	2.4	3.2	12

Lamp Lifetime

	(hours)	Standard/Low Loss	Electronic
Average Lamp Life		8000	12000

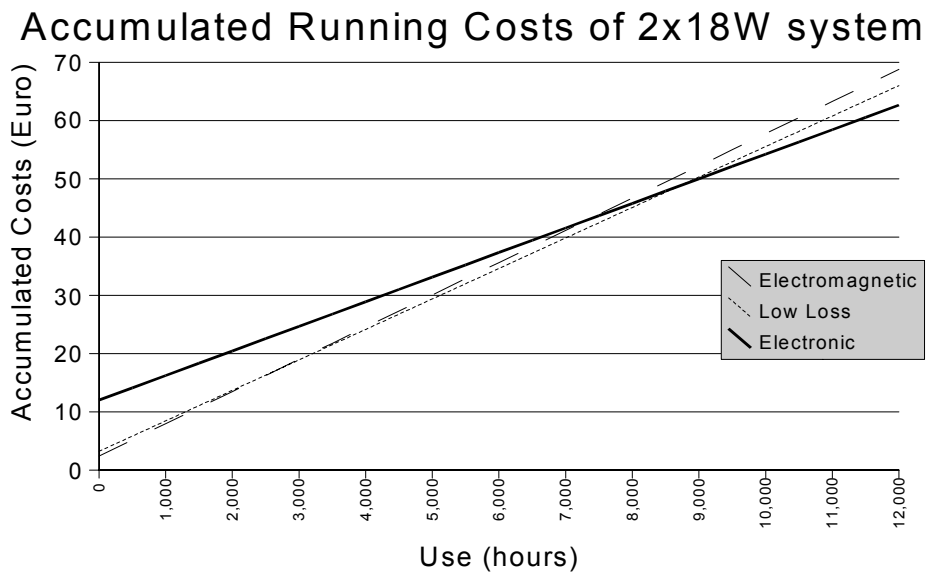


Figure 1. Comparison of accumulated running costs (initial ballast purchase costs, energy acquisition and lamp replacement) for 2x18W lamp combinations using standard magnetic (Class D), low loss (Class B2) and electronic ballasts (Class A2) . The use of low loss ballasts becomes economic after 3000 hours of use and electronic ballasts after 7500 hours.

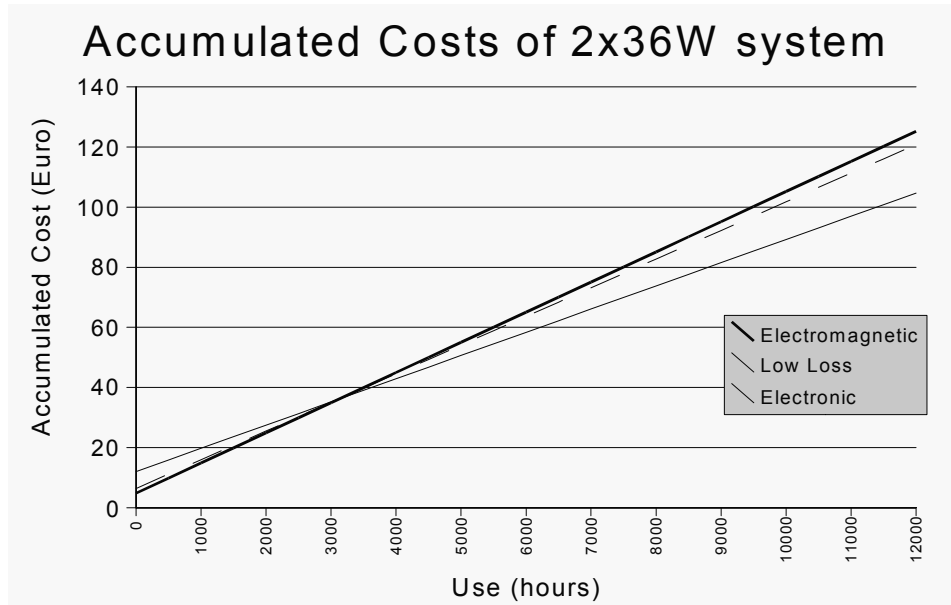


Figure 2. Comparison of accumulated running costs (initial ballast purchase costs, energy acquisition and lamp replacement) for 2x36W lamp combinations using standard magnetic (Class D), low loss (Class B2) and electronic ballasts (Class A2). The use of low loss and electronic ballasts both after roughly 3500 hours (thus the use direct passage to electronic ballasts is recommended).

Figure 1 and Figure 2 report the accumulated costs as a function of system use. The PROST specifications are derived by considering that the break even point at which the accumulated costs of systems with low loss and electronic ballasts equals the accumulated costs of standard ballast systems, occurs after five years. Thus for example in the case of 2x18W systems, for electronic ballasts this occurs after 7500 hours, which considered over five years of invariable annual usage, equates to an average use of 7,500hours / 5 years =1,500 hours/year.

Though we retain the purchase price used in the analysis is justified (Table 5), we nevertheless consider the cost effectiveness of using higher cost electronic ballasts, (Table 6). Even with a purchase price of 25 Euros, the use of electronic ballasts generally proves cost effective over ten years. The single exception is for 2x18W (or 4x18W) systems with low annual use (1,200 hours/year).

Table 6. Sensitivity on the economics of using electronic ballasts (Class A2) as a function of their cost. The table reports the Internal Rate of Return of the initial investment (Investment = marginal cost of purchase of electronic ballast compared to standard electromagnetic ballast). The shaded cells indicate the likely scenario.

System Type	Purchase Price Electronic Ballast (Euro)	Annual Use			
		(hours/year)	(hours/year)	(hours/year)	(hours/year)
		700	1200	2000	3600
2x18W, 1x36W, 1x36W	15		21%	35%	97%
	25			10%	34%
2x36W	15	27%	67%	203%	>1000%
	25	2%	18%	45%	133%

Considered over 10 years, the initial additional investment purchase price of electronic ballasts is amply repaid, providing notable returns. Ten years probably itself represents a conservative estimate of ballast' lifetime (commonly reported as 15 years). Thus the specifications defined in Table 1 provide a good compromise between achieved lifetime savings and short term financing.

Existing National Purchase Specifications

FEMP

The FEMP recommendations are based on the Ballast Efficiency Factor, which is defined as the ratio of the ballast factor (BF) to input watts. European ballast manufacturers do not normally grade ballasts in terms of Ballast Efficiency Factor, or Ballast Factor and therefore these parameters do not prove a useful tool to direct purchases here.

Working from the financial example provided in the FEMP guidelines it proves possible to define the FEMP recommendation into terms of the European CELMA classes (Table 7).

From which it appears that FEMP recommends at least Celma Class A2 ballasts, irrespective of the hours of use.

However there is some doubt whether the interpretation of the FEMP recommendations offered here is correct, since the recommended power system level for 2 x 32 W tubes is 62 W, which is exceedingly low and probably equates not with Class A2 but with Class A1 dimmable ballasts.

As dimmable ballasts are notably more expensive than standard electronic ballasts and cost effectiveness is achieved only under special circumstances, it is felt such a general recommendation would not be made, and hence the present interpretation is erroneous.

Table 7. FEMP recommendations for electronic ballasts for T8 tubes compared to the CELMA Classification scheme. The comparison is based on example of application provided by the FEMP guidelines, not the guidelines themselves. The comparison seems erroneous.

		Base Model	Recommended Level	Best Available
Ballast BEF		1.09	1.44	1.54
System		2x T12 34 Watts	2x T8 32 Watts	2x T8 32 Watts
Power	(W)	82	62	57
Celma Class B1 Limit		≤82		
Celma Class A2 Limit			≤72	≤72

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At more than 800 h/a, electronic ballasts should be used.

Which equates roughly with the present PROST specification for 2x36 W T8 systems, though is less restrictive of the here defined specification for 1x36 W systems.

In a mature market with list prices of electronic ballasts 30% below the reference value used in the present analysis (10 Euro as opposed to 15 Euro), the City of Frankfurt am Main specification would probably identify general point of cost effectiveness.

Efficient Lighting Initiative

- For New Construction and Significant Renovation (thus complete luminaire replacement), Celma Class A3 systems
- For Replacement Systems in which ballasts are sold separately from luminaires and lamps, Celma Class B1 systems

Considered over the full lifetime of the systems (15 years), the specifications will likely prove cost effective, though no

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analysis is provided by ELI, or made here.

Further Analysis

The present specification considers two of the three most common system combinations presently in use (4x18W, 2x36W, 2x 58W). Defining additional specifications for 58W systems is therefore necessary.

More generally the CELMA classification scheme is articulated on the basis of six fluorescent lamp categories (one linear, and five compact). Within each category, the classification is further articulated on *lamp+ballast* system power, for a total of 29 subcategories.

The need to provide specifications for the 22 compact fluorescent sub categories, depends to a degree on the use of pin based compact fluorescent lamps by the public sector. A recent Save study (Energy Piano, 2001) indicates that 15-25% of fluorescent sources installed in the tertiary sector are (mainly pin based) CFL's, which might indicate a general need for specifications for CFL ballasts. However this figure might be significantly influenced by the retail sector considered in the study.

The two solutions are

- to undertake an analysis to determine which of the 22 Celma categories covering ballasts for compact fluorescent lamps are most used in the public sector. Subsequently collect market purchase prices of the common ballasts in order to determine cost effective usage, and subsequently specifications.
- make a general specification to use Class A2 (non dimmable ballasts), for all pin based compact fluorescent lamps irrespective of usage, on the general principle that this proves costs effective over the lifetime of the system, unless public bodies prove otherwise.

PPS3: PROST Luminaire Efficiency Specifications

Specifications

Table 1. PROST minimum “downward” efficiency specifications for luminaires.

Luminaire Type	IP	Luminaire Downward Efficiency		
		Average	Best	Recommended
		(%)	(%)	(%)
Standard Work Place/Office, Louvered for VDT	< 54	62	73	67
Special Work Place (e.g. laboratories, kitchens)	54 < IP < 65	49	60	56
Industrial	> 65	69	85	73

Note

IP = International Protection

IP20 : Protected against penetration of solid parts with a diameter greater than 12 mm and not protected against liquids

IP40 : Protected against penetration of solid parts with a diameter greater than 1 mm and not protected against liquids

IP54 : Protected against dust and splashes of water

IP 65 : Protected and against dust and jets of water

Luminaire Efficiency

Ratio of light output from luminaire (in lumens) and total light output from the light source (in lumens) which it holds.

To be applied to all purchases.

Replacing a single luminaire with a more efficient model:

- increases the possibility of using a limited number of lamps in a multiple lamp luminaire
- increases the level illumination and thus decreases the probability that users will introduce additional portable light sources (for example desk lamps)

When refurbishing or replacing many luminaries, using more efficient luminaries allows the total installed power to be reduced.

Example of Savings and Costs

The list purchase price of luminaries at the recommended efficiency level and above generally equates with the purchase price of standard efficiency models; i.e. there is limited if no additional cost for purchasing efficient versions.

The purchase price of IP54 protected luminaries at recommended efficiency levels is 30% higher than standard efficient models. However under typical working conditions (3600 hours a year), they nevertheless result cost effective (see Table 3).

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Table 2. Typical list purchase prices for luminaires for 4x 18W T8 tubes with standard electromagnetic ballasts (2 ballasts per luminaire)

Luminaire Type	no. of models in database			List Purchase Price	
	total	at recommended efficiency and above		All models	At recommended level and above
		no.	no.	% of total	(Euro)
Standard Work Place/Office, Louvered for VDT	44	10	23%	77	78
Special Work Place (e.g. laboratories, kitchens)	8	2	25%	128	169
Industrial	17	4	24%	73	77

Table 3 reports the financial savings obtained by introducing luminaires at recommended and best available efficiency levels compared to products of standard efficiency. In all cases luminaires at recommended and best efficiency levels prove cost effective considering a 15 year lifetime.

Table 3. Example of Cost Effectiveness

Luminaire Type	Luminaire Efficiency (%)	No. Luminaires	Total Annual (kwh/year)	Total Lifetime Savings (euro)	Energy Use (kWh/m2yr)	Energy Costs (Euro/m2 yr)	Lifetime Savings (Euro/m2yr)	
Office	Average	0.62	35	11,444		29	2.86	
	Recommended	0.67	32	10,590	819	26	2.65	2.05
	Best	0.73	30	9,720	1,666	24	2.43	4.17
Special Work Place	Average	0.48	45	14,782		37	3.70	
	Recommended	0.56	39	12,671	1,102	32	3.17	2.76
	Best	0.6	36	11,826	1,063	30	2.96	2.66
Industrial	Average	0.69	31	10,283		26	2.57	
	Recommended	0.73	30	9,720	446	24	2.43	1.12
	Best	0.85	25	8,348	2,048	21	2.09	5.12

Cost Effective Assumptions

Table 4.

Single Luminaire Power :	91 W	(2 * 36 W T8 tubes + 19 W ballast)
Operating Hours	3600 hours	
Space Lighting Level	300 lux	
Area illuminated	20m x 20m	ceiling height 2.7 m
Energy Price	0.1 Euro/kWh	
Lifetime	15 years	
Discount Rate	8%	

Note. In the case of smaller spaces (< 400 m²), energy use and energy costs per unit area remain more or less constant; only the total costs and savings change. In smaller spaces there is actually a slight increase of per unit space energy use, since a greater portion of the light output from the luminaires is absorbed by the walls.

Considerations on Recommended Efficiency Levels

The specifications categorise luminaries in terms of three IP levels, which represents a compromise between the 9¹ categories actually defined by standards and the actual requirements of the Public Administration (where office space predominates).

Recommended efficiency levels are based on an analysis of products offered by three important manufacturers (in terms of market presence) of standard luminaries in Italy, together with a comparison of existing national purchase guidelines. The specifications are based on an analysis of the efficiency, cost and general performance of roughly 100 fluorescent luminaries (though the actual offer from of three manufacturers considered is notably larger than this).

Though the specifications are based on an analysis of the efficiency of luminaries for 4 x 18 W T8 fluorescent tubes, they are intended as the absolute lower limit of luminaire efficiency for all lamp types. The average efficiency of luminaries for single T8 tubes is slightly higher than for multiple T8 tubes, but not sufficient to warrant separate purchase specifications.

Luminaries for T8 fluorescent tubes, though not the most efficient, presently hold the greatest market share, and hence the need to provide purchase specifications. The specifications are based only on the **downward efficiency** of luminaries. Upward and downward emitting luminaries generally have a slightly higher overall efficiency than dedicated downward emitting products. However whether the light emitted upwards actually contributes to increasing the level of illumination on the required horizontal surface depends on conditions external to the luminaries (i.e. the colour of the ceiling or walls), which lies beyond the scope of this purchase specification.

The recommended levels generally identify the 25% most efficient products, based on the range of efficiency of the luminaries in the three categories. Thus for example, the range of efficiency of “Standard Work Place/Office, Louvered luminaries for VDT with IP < 54”, is from 47.8 to 73%. The recommended level for purchases is therefore set at $73\% - 25\% \times (73 - 47.8) = 67\%$.

However a check was conducted to ensure that there was an adequate offer of luminaries above the recommended efficiency level (i.e. that the efficiency level was not dragged upwards by a few very highly efficient luminaries). In the case of “Standard Work Place (IP < 54)” and “Industrial luminaries (IP > 65)”, 20% of luminaries lie above the recommended efficiency level. In the case of “Special Work Place (54 > IP > 65)”, it proved necessary to lower the recommended efficiency level to ensure that the offer remained adequate (= 20% of total number of luminaries available).

The recommended efficiency level provides a compromise between product efficiency and offering adequate choice in purchase.

Table 5 provides an overview of luminaire efficiency for different fluorescent lamp types. Luminaires for T5 lamps are slightly more efficient than for T8 lamps and separate purchase specifications could be developed. As the table shows there are examples of extremely highly efficient luminaires for some lamp types. For example one producer achieves a luminaire efficiency of above 90% for CFL 55 W lamps. Though these luminaires should be used when possible, their use might be limited to specific needs since their light control can be less than that offered by louvered luminaires.

¹Not counting the 5 sub categories for each of the 9 categories, which define the impact resistance of luminaries.

PROST – APPENDIX 3c

Table 5. Typical luminaire efficiencies

	Lamp Type	Range of Luminaire Efficiency (%)
Diffuser/Prismatic	T8	42-62
White painted reflectors	T8	55-65
Aluminium reflectors	T8	57-73
Aluminium reflectors	T5	66-75
Aluminium reflectors	CFL 55W G11	63-90
Industrial	T8	58-84

Existing National Purchase Specifications

FEMP

The FEMP guidelines recommend luminaires using the Luminaire Efficiency Rating (LER). The LER is not widely used in Europe. However by making reasonable hypothesis' regarding a number of parameters it is possible to translate the FEMP LER recommendations to standard luminaire efficiency recommendations.

Table 6 elaborates the LER for three luminaire types and compares these with the efficiency recommendations for the three roughly comparable luminaire categories used in the PROST specifications.

Overall the FEMP and PROST specifications match; however there are discrepancies on specific categories. This might be due the differences in naming. However the FEMP recommendations note that

“VDT-preferred” luminaries , while reducing glare on computer screens may be less efficient than other models”.

and indeed the efficiency recommendations offered by FEMP for “VDT-preferred luminaries are lower than for other categories.

However from the examination of products available on the market in the present study this does not seem to hold true. Thus the PROST efficiency specifications for VDT use are higher than FEMP recommendations.

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Table 6. Elaborated extract from FEMP recommendations “How to Buy Energy-Efficient Fluorescent Luminaires”

FEMP Recommendations				PROST Specifications	
Luminaire Type	No. Of Lamps	Luminaire Efficiency Rating	Luminaire Efficiency (Elaborated)	Luminaire Type	Luminaire Efficiency
Lensed	2	62	67%	Special Work Place (Kitchen, Laboratory)	54 < IP < 65
	3	61	66%		
	4	61	66%		
VDT Preferred – Louvered	2	50	52%	Standard Work Place (Louvered/VDT)	< 54
	3	51	55%		
	4	54	58%		
Industrial	Four Foot	2	67	Industrial	> 65
	Eight Foot	2	68		

City of Frankfurt am Main

Lighting efficiency of luminaires should be at least 80 % (e.g. specular louvered luminaries).

Which considering the analysis conducted within the present study seems excessively restrictive. From the present study such high efficiencies are achieved in louvered VDT recommended luminaries only in the case of combined upward and downward emitting products, in which the direct downward efficiency is of the order of 60%.

Further Study

The present study is based on an analysis of products offered by the three manufacturers which dominate supply in Italy. The specifications might be improved (increased accuracy) by analysing the offer in other Member States. Certainly the purchase specification for the “Special Work Place (e.g. laboratories, kitchens) 54 < IP < 65” category was based on analysis of only 10 products. However anecdotal evidence would suggest that there is no significant cross country variation in the quality of luminaries.

As noted the specifications categorise luminaries in terms of three IP levels, which represents a compromise between the 9² categories actually defined by standards and the actual requirements of the Public Administration (where office space predominates).

An analysis involving more products might allow specifications be extended to each of the nine categories. Obviously any increase in the number of categories increases the complexity of use. Also it is underlined that in the case of specific demonstrated requirements, for example where there is a special need for IP 40 luminaries, the purchasing officer can ignore the present purchase specification.

²Not counting the 5 sub categories for each of the 9 categories, which define the impact resistance of luminaries.

PPS4: PROST T5 System Specifications

Specifications

Table 1, Table 2, Table 3 and Table 4 indicate under which annual use conditions alternative lighting system prove economic.

Table 1. Overall choice of system

System Type	When Alternative System Is Economic		
	T8 4x18W	T5 2x35W	T5 4x14W
T8 2x36W (34W)	Never	If correctly designed See Table 2	Never
T8 4x18W (16W)	-	Most likely See Table 3	See Table 4
T5 4x14W	See Table 4	Always	-

Table 2 . The maximum marginal purchase price at which T5 2x35 W luminaires prove economic compared to T8 2x36W luminaires with electronic ballasts. That is, T5 2x35 W luminaires should be chosen over T8 2x36 W models if the extra price of the T5 compared to the T8 luminaire is less or equal to the figure reported in the last row of the table.

For spaces above 80m²

Annual Use	(hours)	2000	3000	4000	8000
Acceptable Extra Cost for T5 Luminaire + Tubes	(euro)	16	17	18	21
Likely Additional Lamp Cost per T5 tubes	(euro)	5.3	5.3	5.3	5.3
Acceptable Extra Cost for T5 Luminaire	(euro)	11	12	12	15

Table 3. The maximum marginal purchase price at which T5 2x35 W luminaires prove economic compared to T8 4x18W luminaires with electronic ballasts. That is, T5 4x14 W luminaires should be chosen over T8 4x18 W models if the extra price of the T5 compared to the T8 luminaire is less or equal to the figure reported in the last row of the table.

Annual Use	(hours)	2000	3000	4000	8000
Acceptable Extra Cost for T5 Luminaire + Tubes	(euro)	71	87	103	166
Likely Additional Lamp Cost per T5 tubes	(euro)	-1.5	-1.5	-1.5	-1.5
Acceptable Extra Cost for T5 Luminaire	(euro)	73	89	104	167

Table 4. The maximum marginal purchase price at which systems composed of T5 4x14 W luminaires prove economic compared to T8 4x18W luminaires with electronic ballasts. That is, T5 4x14 W luminaires should be chosen over T8 4x18 W models if the extra price of the T5 compared to the T8 luminaire is less or equal to the figure reported in the last row of the table.

Annual Use	(hours)	2000	3000	4000	8000
Acceptable Extra Cost for T5 Luminaire + Tubes	(euro)	13	19	26	51
Likely Additional Lamp Cost per T5 tubes	(euro)	7.6	7.6	7.6	7.6
Acceptable Extra Cost for T5 Luminaire	(euro)	5	12	18	44

Additional Specifications

T5 fluorescent tubes are not available with a Colour Rendering Indexing of 90 or above. They can not be used therefore in certain specialist applications; for example in hospital operating theatres, dental studios and cloth retailers.

Comments

The specification compares the economics of T5 systems with T8 systems using electronic ballasts. The economics of using T8 systems with electronic ballasts rather than T8 systems with standard ballasts is considered in an another PROST specification.

Considering total lifetime costs, T8 2x36 W systems with electronic ballasts represent the most economic solution under almost all conditions.

T5 2x32W systems can prove cost effective compared to T8 2x36W systems, if it proves possible to reduce the number of the former installed luminaires with respect to the latter. Though Table 2 indicates this to be a factor of space surface area, this is a slight simplification and generally savings can be achieved only by ensuring a correct design of the plant.

T5 luminaires provide an economic alternative to T8 4x18 W systems (with electronic ballasts) if the conditions in Table 3 and Table 4 are met.

The choice of T8 4x18W systems rather than T8 2x36W systems will depend on non economic considerations (space ergonomics, aesthetics, etc.).

Example of Savings an Costs

Table 6 compares the economics of operating T5 2x35W and T8 4x18W systems following the specification given in Table 3.

We consider a 71 Euro price premium for the T5 luminaire (compared to a T8 model). Operated for 2000 hours per year this price premium is repaid in eight years. For plants with higher annual operating hours, pay back is reduced and the Internal rate of Return on the investment increases.

Table 7 compares the economics of using T5 4x14W and T8 4x18W systems following the specification given in Table 4.

We consider a 18 Euro price premium for the T5 luminaire (compared to a T8 model). Operated for 4000 hours per year this price premium is repaid in eight years.. For plants with lower annual operating hours, pay back increases above ten years, and the investment provides negative returns over the lifetime of the plant (conservatively considered as ten years).

Cost Effective Assumptions

Table 5.

Space Lighting Level	500 lux	
Area illuminated	20m x 20m	ceiling height 2.7 m
Energy Price	0.1 Euro/kWh	
Lifetime	10 years	conservative estimate

The technical characteristics of the T5 and T8 systems are detailed in Table 8.

Table 6. Economics of using T5 2x35W luminaires compared to T8 4x18W luminaires.

System Type	Luminaire				Illuminated area (m2)	No. of Luminaires	Total Investment Cost (Euro)	Annual Running Costs (as a function of operating hours)				
	List price	Discount	Purchase Price					2000 (euro)	3000 (euro)	4000 (euro)	8000 (euro)	
	(Euro)		Luminaire (Euro)	+Lamps (Euro)								
T5 2x35W	209	20%	167	179	25	3	538	47	71	95	190	
T8 4x18W	120	20%	96	110	25	4	439	59	89	118	237	
Difference	89		71				99	12	18	24	47	
							Payback	(years)	8	6	4	2
							IRR		3%	12%	20%	47%

Table 7. Economics of using T5 4x14W luminaires compared to T8 4x18W luminaires.

System Type	Luminaire				Illuminated area (m2)	No. of Luminaires	Total Investment Cost (Euro)	Annual Running Costs (as a function of operating hours)				
	List price	Discount	Purchase Price					2000 (euro)	3000 (euro)	4000 (euro)	8000 (euro)	
	(Euro)		Luminaire (Euro)	+Lamps (Euro)								
T5 2x14W	143	20%	114	135	25	4	541	53	79	106	211	
T8 4x18W	120	20%	96	110	25	4	439	59	89	118	237	
Difference	23		18				102	6	10	13	26	
							Payback	(years)	16	11	8	4
							IRR		-8%	-1%	4%	21%

Considerations on Specified Efficiency Levels

In a number of cases the present specification calls upon purchase officers to confront the list price of alternate products. This increases the complexity of the purchase specification, compared to other PROST purchase specifications, by placing an onus on purchase officers to collect and compare the purchase price of alternate T5 and T8 products.

However T5 systems are relatively new and consequently compared to T8 systems there are a limited number of products on the market. Given the relatively limited number of products available, the average price of T5 luminaires is strongly influenced by a few expensive models. Basing the purchase recommendations on average prices of T5 products would lead to a general specification not to buy T5 luminaires

However making such a general negative specification is not felt to be helpful, considering that there are nevertheless individual relatively low price T5 products which do prove economic compared to T8 systems.

In addition, given the relative newness of the products, we might expect prices to fall in the near term as the market matures. Thus identifying the acceptable price premium for T5 products is felt to be the most flexible solution considering present market conditions.

The specification is made by considering the annual running costs and consequential relative savings of operating alternative competing systems (for example a system composed of T8 4x18W luminaires and a system composed of T5 2x32 W luminaires). The “acceptable” price premium is determined by considering that annual savings accumulated over eight years are used to cover the original marginal investment cost of the efficient system (i.e. an eight year payback period).

The annual running costs are based on the total system power, which itself is a product of single luminaire power and the total number of luminaires installed. The total number of luminaires required to illuminate a space is determined using the “Total Flux” method:

$$N = \frac{E \times A}{N_e \times F_l \times U \times M_f}$$

N = number of luminaires

E = average illumination on horizontal surface

A = illuminated area

N_e = number of lamps per luminaires

U = utilisation factor

M_f = maintenance factor

A necessary simplification is made by equating overall luminaire efficiency (given Table 8) with the space Utilisation Factor.

The competing luminaires provide different total luminous output (depending on luminaire optical efficiency and lamp output). In “larger” spaces it proves possible to balance single luminaire output with the corresponding number of luminaires to provide the required level of illumination; thus the total number of luminaires of competing systems might vary. However since it is not possible to install fractions of luminaires, smaller spaces often require the same number of

competing luminaires. In these cases the variations in luminous output offered by different luminaires result in slight variations in space illumination levels.

The technical characteristics of the systems considered in the study are defined in Table 8.

Table 8. The technical characteristics of the T5 and T8 luminaires considered by the analysis.

System Type	Lamps Output	List Purchase Price	Typical Efficiency*	No of Lamps	Luminaire Output			Power (W)	
					Total (Lumen)	+Luminaire Efficiency* (Lumen)	+Maintenance Coefficiente (Lumen)		
	(Lumen)	(Euro)			(Lumen)	(Lumen)	(Lumen)	(W)	
T5	2x35W	3650	7.62	73.00%	2	7300	5329	4796	79
T5	2x28W	2900	7.33	73.00%	2	5800	4234	3811	64
T5	4x14W	1350	6.65	73.00%	4	5400	3942	3548	66
T8	2x36W	3350	4.29	71.00%	2	6700	4757	4281	71
T8	4x18W	1350	4.29	71.00%	4	5400	3834	3451	74

*We equate Luminaire Efficiency with the Coefficient of Utilisation. This is a necessary simplification to arrive at generalised specifications.

Table 9. Parameters used in the analysis.

Acceptable Payback	Years	8
Energy Price	Euro/kWh	0.1
Lighting Level	Lux	500

The fact that T5 systems do not prove particularly advantageous compared to T8 systems can in part be understood by considering the efficiency of the different systems.

Table 10 shows T5 lamps generally to be slightly more efficient than T8 lamps. However the difference in efficiency between T8 36W tubes and T5 35W tubes is less than 3%. Further if we consider the efficiency of the total system; namely tube, ballast and luminaire, this slight margin is even further reduced.

The economics of operating T5 systems (compared to T8) thus proves difficult if we consider that the price premium of T5 luminaires is roughly of the order of at least 20%.

Table 10. Efficiency of T5 and T8 systems. Note we consider a 0.96 ballast factor in relation to the T8 lamps, as commonly though not universally reported by manufacturers of electronic ballasts.

System Type	Tube Efficiency (lumen/watt)	Tube+ Ballast Efficiency (lumen/watt)	Tube + Ballast + Luminaire Efficiency (lumen/watt)
T5	2x35W	104	61
T5	2x28W	104	60
T5	4x14W	96	54
T8	2x36W	101	60
T8	4x18W	81	47

Existing National Purchase Specifications

There are no known existing guidelines which explicitly recommended the purchase of T5 systems. Their use might be implicitly supposed through target value guidelines (i.e. where kWh/m²/year values for illumination are defined), but this has not been checked.

Manufacturers of lamps report up to 20% savings can be achieved by using T5 instead of T8 systems. It would appear however that the comparisons refer to T8 systems operated on standard or low loss electromagnetic ballasts. Certainly the present analysis which considers T8 systems operated on electronic ballasts, though based on the same manufacturer published technical data shows no such savings.

Interestingly suppliers of luminaires do not provide any economic evaluation of using T5 systems, though they do generally provide examples of financial savings offered by using say electronic instead of standard electromagnetic ballasts. It would appear, as in part confirmed in this specification, that T5 systems are generally not economic compared to alternative T8 systems. As a marketing policy, the present price premium for T5 products is based on improved ergonomics and aesthetics compared to T8 systems, which is not directly recoverable from improved energy efficiency.

Further Analysis

The present specification considers T5 (16 mm) tubes operated on high frequency ballasts. The complete set of T5 lamps is listed in Table 11.

T5 lamps operated on electronic ballasts (indicated in Table 11), are a relatively new development and offer an alternative to T8 systems for space illumination.

Of the T5 tubes operated on electronic ballasts, the 14, 21, 28 and 35 W models offer the highest luminous efficiency, and of these the 14, 28 and 35 W models are generally catered for by luminaire manufacturers in their standard office and workplace product ranges. The present analysis provides a specification for the 14 and 35 W types. Though not reported in the present specification the analysis looked at 28W models, and found similar results to the T5 35W models; i.e. limited economics compared to alternative T8 systems. The specification could be completed by finalising and reporting the analysis in relation to T5 28W luminaires.

The 24, 39, 49, 54 and 90 W models offer a lower luminous efficiency than the other high frequency T5 lamps and would not seem to present an alternative solution to standard T8 systems. However a more thorough analysis might lead an explicit specification not to buy these models, unless particular space conditions merited otherwise.

As noted, the technology is new and T5 products might be expected to fall in price as the market matures. However as the specification is not based directly on the present market price of T5 products, it will be unaffected by these changes. The

downside of this, as noted, is that it increases the complexity of use by purchase officers. Thus if there were signs that the market were effectively maturing, (which would most probably require liaison with manufactures), a more definitive efficient specification might be developed based on future matured prices.

Table 11. Set of T5 tubes marketed in Europe. Shaded cells indicate tubes for which the present document provides purchase specifications.

Lamp Type Diameter (mm) Length (mm) Nominal Tube Power (W)	T5													
	16													
	136	212	288	517	549	849	549	1149	1149	849	1449	1149	1149	
	4	6	8	13	14	21	24	28	35	39	49	54	80	
Operated on Electronic Ballasts					X	X	X	X	X	X	X	X	X	X
Used in Standard Luminaires					X			X	X					

PPS5: PROST Window Specifications

Specifications

Table 1. Minimum acceptable performance characteristics of windows (Insulating Glazing Units)

Climate Zone	Cooling Requirement	U Value (W/m2 K)	SHGC	T _v * Best Available
Heating	no concern	≤1.3	≥0.5	0.6
	of concern		≤0.4	0.5
Heating and Cooling	limited concern	≤1.6	≤0.5	0.6
	some concern		≤0.4	0.5
Cooling	real concern	-	≤0.3	0.4

SHGC = Solar Heat Gain Coefficient

*This column provides information only; it is not a requirement.

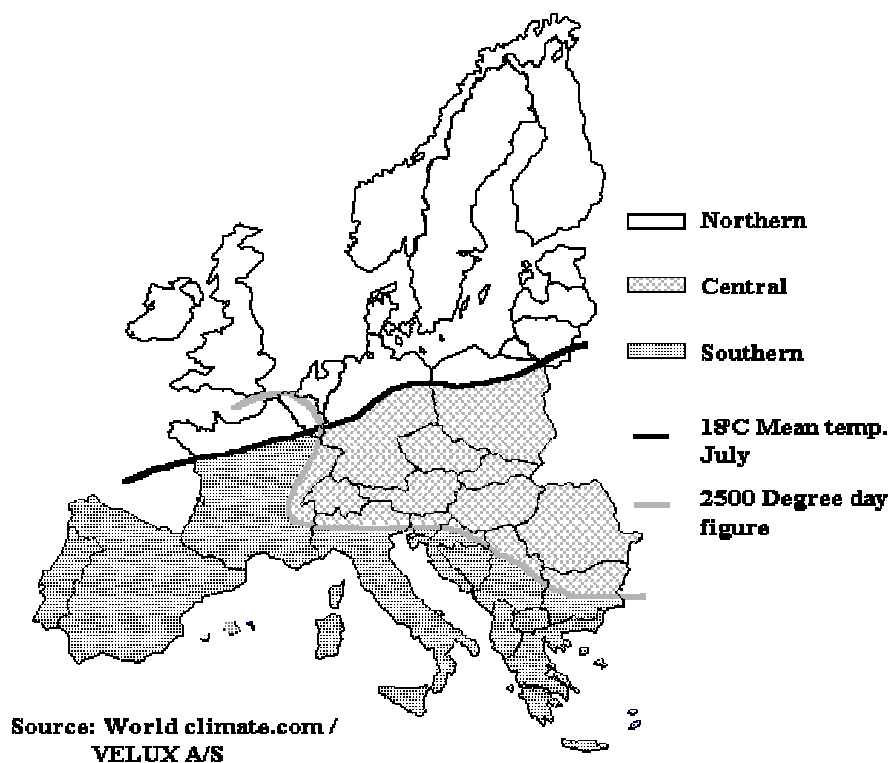


Figure 1. European climate zones. Source world climate.com from British Fenestration Rating Council web site.

Northern = Mostly Heating
 Central = Heating and Cooling
 Southern = Mostly Cooling

Comments

- The map is very indicative. Only in truly Mediterranean climates should windows be chosen on the basis of SHGC alone.
- In some hot climates where winters are mild it might seem reasonable to select a single-glazed window with a low

Solar Heat Gain Coefficient rather than a more typical double glazed unit. However single glazings have a more limited range of solar control so a double glazed unit may be the overall best solution.

Considerations on Recommended Efficiency Levels

There is a significant amount of scientific and commercial literature reporting the benefits of Low E and Spectrally Selective Glazing¹. However for the the most part this tends to consider the physics of Low-E and Spectrally Selective glazings. Quantitative analysis tends to concentrate on glazing and window characteristics, for example window shading coefficient or U values.

Though much qualitative assessment can be found, less quantitative information is available relating to the actual performance of advanced glazing when installed in buildings; specifically the nature of building energy and power savings and most importantly the economics of use.

Certainly there is no existing structured cross country analysis of the performance of advanced glazing articulated according to national/regional building stock types and categories, and climate zones, which would allow this present text to identify “typical” energy savings potentials and pay-back times. (This is considered below in the section Further Analysis).

Such an analysis is far beyond the scope of this project, and possible any other. The British Fenestration Rating Council is currently leading a EU funded project² to develop a European wide energy rating system for glazing. Part of that study will attempt to establish representative climate zones for Europe in which to categorise the performance of the many Low-E and Spectrally Selective glazings. However it is doubtful that even this project will associate “typical” energy savings with given glazing types or categories. Indeed existing glazing national energy labels, where they exist (for example, Australia, Canada, UK, USA) categorise glazing, based on the physical performance characteristics of the glazing (for example U value, shading coefficient) and not on end use energy savings which the glazings offer.

However though it proves impossible to identify “typical” savings the literature consistently reports Low-E and Spectrally Selective glazing to be cost effective. The present specification was arrived at by considering:

- such general considerations of cost effectiveness
- together with quantitative analysis
- and considerations on current trends in national building codes and practices

Each of the three points is considered in further detail in the sections below. Summarily the analysis detailed below indicates that advanced glazings commonly (if not typically) provide savings in cooling and heating energy demand in the order of 20%, with additional significant reductions to system installed power (with consequential lower capital costs) and improved space comfort levels. Low-E and Spectrally Selective glazings always prove cost effective over the lifetime of the product (considered maybe conservatively as 25 years). Advanced glazing is however most cost effective (payback times of less than 10 years) if used in cooling load dominated buildings in warmer climates (since the price of electricity used for cooling is more expensive than the price of heating fuel). When used to replace single pane glazing, payback times can be as little as 4 years.

All of which points to the benefits of installing advanced glazing when ever possible. However it is also important to consider that in most countries (with the exception of Greece, Italy, Ireland and Spain) advanced glazing is now generally the default glazing type installed in new buildings irrespective of the actual national building codes (which are maybe less stringent). Thus if the present specification is do more than simply reconfirm existing building practice (in most countries), and confirm the leadership role required of the public administration, it needs to identify the best Spectrally Selective and Low-E glazing types available. The specification defined in Table 1 hopefully does this.

¹Where the distinction is necessary we use Low-E to identify glazings used to reduce heat loss and Spectrally Selective for glazings used to reduce solar gains. Otherwise we use the term advanced glazing generically to refer to both types.

²SAVE II , European Window Energy Rating System (EWERS), /www.bfrc.org/save

PROST – APPENDIX 3e

The present purchase specification is made by considering the range of glazing types on the market (considered in more detail below) and international experience on their use. However the analysis performed here to identify the “best glazing” suitable for Europe is very limited. Importantly there is no desire to duplicate the work of the European SAVE project currently underway to develop a European Window Rating System (see above), even if there were sufficient resources within the present project to do so (which there are not). Thus the present specification serves as a temporary measure to guide purchases in the PA until such time the the European Window Rating Scheme is operational, at which point the present specification will need to be updated.

Finally we also note that even if the economics of using Low E-glazing might possibly prove marginal in certain conditions (due to the possible elevated purchase cost), the extra CO₂ emissions and energy use in the industrial deposition of the Low-E coating on clear glass is negligible - 1/1000 of the savings likely to be achieved during the lifetime of the product³. Thus the Public Administration will always satisfy its wider social objective of minimising its environmental impact by using advanced glazing.

Choice of Performance Requirements

The following graphs shows typical performance ranges of insulating glass units (IGUs). In this case the data refers to product ranges offered by a single important international manufacturer.

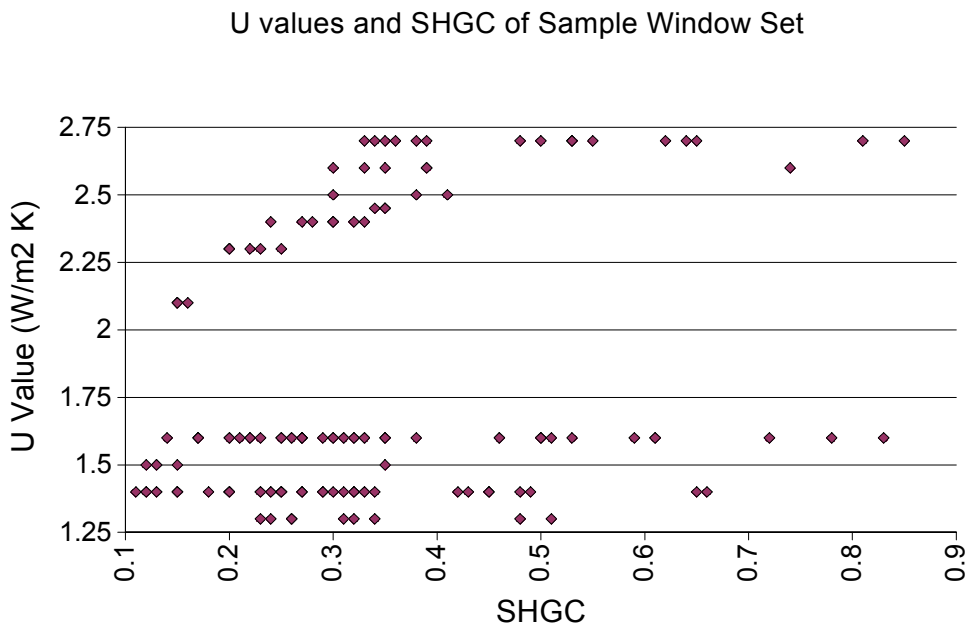


Figure 2. Typical performance characteristics of Insulating Glass Units

The recommended performance levels are set by considering the following:

For Climates with High Heating Loads

Windows with a high U value to prevent heat loss (max. 1.3 W/m² K) :

1. where cooling is not a concern: windows with a low shading coefficient (0.5 or greater) to allow winter solar gains to

³“Low-e glass in buildings, impacts on the environment and on energy savings”, Groupement Europeen des Producteurs de Verre Plat (GEPVP)

PROST – APPENDIX 3e

offset a portion of the heating needed. The combination provides for windows of high visible transmittance (> 0.6).

2. where cooling is a concern : windows with a lower shading coefficient (0.3). The combination provides for windows of good visible transmittance (> 0.4).

For Climates with Heating and Cooling Loads

Windows with a relatively high U value to prevent heat loss (max. $1.6 \text{ W/m}^2 \text{ K}$)

3. where cooling is not of real concern: windows with a low shading coefficient (0.5 or greater). The combination provides for windows of high visible transmittance (> 0.6).

4. where cooling is of real concern : windows with a lower shading coefficient (0.4). The combination provides for windows of good visible transmittance (> 0.5).

For Climates with High Cooling Loads

Windows with the lowest shading coefficient (max. 0.3) which at the same time do not unduly attenuate light transmittance (> 0.4).

General Considerations on the Economics of Low-e and Selective Glazing

“In general Spectrally Selective glazing pays back in 3 to 10 years for US Commercial buildings where it replaces clear single pane or tinted double pane glass and for most commercial buildings in the southern United States where it replaces Low-E double pane windows”

from **Federal Technology Alert, EE-0173, Spectrally Selective Glazing, Department of Energy**

“The additional investment required to incorporate low-e double glazing instead of ordinary double glazing represents on average less than 0.3% of the cost of a new dwelling. In some countries the payback can be less than three years.

In countries with existing thermal regulations, such as in Germany experience shows that the additional cost has decreased considerably over the last ten years. In such a well developed market the market price of low-e double glazing is very close to the one of ordinary double glazing. “

from **“Low-e glass in buildings, impacts on the environment and on energy savings”, *Groupement Europeen des Producteurs de Verre Plat (GEPVP)* based on the Thermie study “Major energy savings, environmental and employment benefits by double glazing and advanced double glazing”, first completed in 1995 and updated in 2000.**

Quantitative Analysis

UE Project IMAGE, Implementation of Advanced Glazing in Europe

The IMAGE project aimed to generate performance information for advanced glazing and identify opportunities for applications.

As part of the study, detailed building thermodynamic simulations were undertaken on 9 buildings across Europe. Three of the buildings were in the Scotland, four in England, one in the north of France and one in Denmark.

The analysis highlighted the energy savings and system power reductions, as well as changes in comfort levels offered by the (modelled) glazing retrofits. The results listed in Table 2, show the advanced glazings to offer discrete if not significant energy savings (up to 20%) in most applications as well as providing other improvements to space comfort levels.

However whilst the IMAGE project aimed to identify the cost-benefits of using advanced glazing, it actually stops short of determining the economics of the retrofit options analysed.

The other limitation of the IMAGE project, is that the building analysed were concentrated in the UK with its

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temperate climate. No analysis was conducted in climates where cooling loads predominate.

Table 2. Effects of introducing Low-e and selective Glazing. Results from EU funded IMAGE project which looked at nine buildings in Europe..

Parameter	Impact	Savings	Comments
Heating Capacity	Moderate	5 - 8%	in offices where the peak heating capacity is dominated by ventilation air preheating; in office spaces with high casual heat gains, and therefore low heat demand' in buildings such as schools and offices where the dominant heat loss paths are infiltration and/or opaque fabric conduction.
	High	20%	in highly glazed spaces with low infiltration rates.
Cooling Capacity	Moderate	11%	in offices with effective structural solar shading.
	High	30 - 60%	in highly glazed spaces where a major component of the heat gain is due to direct and indirect solar gain; in mid-European coastal climates where the central ventilation plant cooling loads are moderate due to the lower ambient summer temperatures in summer. Note that in such climates the lower U-Value of solar control glazing will tend to increase the peak cooling capacity (e.g. by up to 5%) because of the reduction in the heat loss, which may not occur in warmer climates.
Heating Energy	Low	0.6 - 9%	in the same cases as listed above under Heating Capacity: Moderate Impact.
	Moderate	10 - 18%	in buildings with low U-value triple glazed system; in highly glazed spaces with low U-value, solar control glazing to strike an effective balance between thermal and solar control.
Cooling Energy	Moderate	10 - 14%	in buildings where effective structural solar shading is applied.
	High	51 - 71%	where the principal cooling load component is due to the solar gain through the glazing. In such cases, solar control glazings therefore have the potential to deliver significant energy savings.
Lighting Energy		7 - 10%	depending on degree to which the advanced glazing component changed the visible transmittance.
Thermal Comfort			Low U-value glazing delivers significant increases resultant temperatures during in winter, generally maintaining temperatures within the comfort zone. Low U-value glazing causes moderate increases in resultant temperatures during summer, generally increasing the overheating tendency. Solar control glazing significantly decreases the resultant temperature in summer, generally maintaining temperatures within the comfort zone.
Daylight Availability			All advanced glazing systems had good visible transmittance and therefore only marginally decreased in the daylight availability was pointed out.
On Visual Comfort			Light redirecting and diffusing systems were observed to significantly improve visual comfort.

Economics of Selective Glazing in Warm Climates (Las Angeles, Miami and Phoenix)

The Federal Technology Alert EE-0173, published by the US Department of Energy offers an analysis of the cost-effectiveness of using Spectrally Selective and Low-E glazing for a commercial internal load dominated building considered in four representative climates in the US; Madison, Los Angeles, Miami and Phoenix. Madison, Wisconsin

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in the Great Lakes area has cold winters and hot summers, and has thus both heating and cooling requirements. However buildings in Los Angeles, Miami and Phoenix having cooling dominated loads.

The analysis considered six glazing types, used in varying proportions, from 15 to 60% of the exterior wall area of the building. Cost effectiveness of the use of Spectrally Selective and Low-E glazing was determined in terms of simple pay-back and peak demand reduction.

A summary conclusions of the analysis are given below. There maybe some limit in transferring results of cost effectiveness in the US to Europe; for example building construction techniques are likely to be different. However US climates are similar to those in the EU, as is the the cost of the advanced glazing used in the analysis (Table 3). Also considering that energy costs in the US are slightly less than in the EU, which reduces the relative benefits (w.r.t. to the EU) of saving energy it could be argued that the analysis provided by the EE-0173 represents a worst case scenario for the EU.

Some of the conclusions of the EE-0173 are:

- Selective glazing with high daylight transmission are cost-effective in commercial buildings with relatively small glazing areas throughout the US. Selective glazing with moderate daylight transmission ($T_v=0.4$) are cost effective in buildings with large glazing areas throughout the US.
- Selective glazing is most cost effective (payback less than ten years) if used in cooling dominated building types, in warmer climates and with day lighting controls. In colder climates, like Madison, Wisconsin, these glazing are also cost-effective because spectral selectivity reduces cooling loads during the summer and low emmissivity and conductivity reduce heating loads during the winter
- Selective glazing will payback within 4 - 10 years for commercial buildings that currently have clear, single pane or tinted, double glazing glass throughout most of the US. Selective glazing will pay back within 4 to 10 years for some commercial buildings in the southern US if the baseline is low emmissivity double pane windows.
- In the analysis conducted, first-cost savings associated with downsized mechanical systems (resulting from reductions in peak demand) were not incorporated in the cost savings; these savings may reduce payback periods.

Table 3. Glazing purchase price and performance characteristics used in EE-0173 cost-benefit analysis. Purchase prices compare to those in place in Europe.

Description	T_v	SHGC	$(T_v/SHGC)$	U-Factor (W/m ² -K) (W/m ² -k)	Cost Euro/m ² (Euro/m ²)
Single Clear	0.88	0.83	1.06	6.17	27
Double low-e	0.44	0.37	1.19	1.78	70
Double Selective Clear	0.68	0.42	1.62	1.64	77

Table 4. Cost of energy used in the EE-0173 cost-benefit analysis (USA), compared to typical costs in Europe (EU).

<i>Eurocents/kWh</i>	USA	EU
electricity	6.4	10
heating fuel	1.2	4

Building Regulations for Windows in European Countries

This section is an abridged version of the paper developed by Rick Rick Wilberforce of Pilkingtons and available from the British Fenestration Rating Council web site. The paper was last updated on 25th February 2002.

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Table 5. Building Regulations for New Buildings in Europe.

Country	Window U-Value	Current Standard Practice	Future Developments
Austria	1.9	Low E double glazing and argon.	Declared aim to move to 1.1
Baltic States	-	Triple Glazing or Low E double glazing.	Currently writing Regulations. Likely to match Scandinavian standards.
Belgium	3.5 (2.5 in Brussels Region)	Ordinary double glazing (Low E double glazing in Brussels Region)	Flanders Region intend to move to U2.0 in 2002.
Denmark	1.8	Low E double glazing	Tightening expected about year 2005. Evaluations of U1.3 taking place.
Finland	2.1	Triple (2 + 1), many with Low E and argon.	U1.4 proposed. Implementation early 2003.
France	Volumetric, implying a window U2.4. There are also requirements to minimise solar gain in summer.	New Regs came into effect June 2001. Likely to lead to Low E double glazing becoming common practice.	New Regs only just implemented.
Germany	Volumetric	Low E double glazing and argon.	
Greece	2.5 in the north, 3.0 in the south	Double glazing, increasingly moving to low E.	
Ireland	Double glazing	Ordinary double glazing	Consultation document issued September 2001. Proposes U2.2 from July 2002 (including replacement windows).
Italy	Volumetric	Ordinary double glazing in the north, single in the south.	U2.8 to 5.2 (depending on climatic zone) currently being proposed.
Luxembourg	2	Low E double glazing	
Netherlands	Total energy consumption (EPC), with U-value limits	Low E double glazing	U1.2 being proposed by government. EPC to be improved every year.
Norway	1.6	Low E double glazing and argon.	
Poland	2.6	Low E double glazing	
Portugal	4.2	Single glazing	
Russia	1.8*	Low E double glazing	
Slovakia	2.0 (for large bldgs)	Low E double glazing	
Spain	Volumetric	Single glazing	Regulations under review. New standards in 2002.
Sweden	Volumetric	Triple glazing, often with Low E and argon.	Overall tightening of about 25%, year 2003. U1.3 has been signalled.

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Country	Window U-Value	Current Standard Practice	Future Developments
Switzerland	Volumetric	Low E double glazing	
U.K.	Window U = 2.2 (metal windows) and 2.0 (non-metal).	Low E (hard coat) double glazing	

Table 6. Building regulations for existing buildings in Europe

Country	Window U-Value	Conditions
Denmark	1.8	Any window which is replaced, (when a building permit is required).
Germany	1.7 (whole window) 1.5 (glass)	When 20% or more of windows in any façade are replaced.
Poland	2.6	Any window which is being replaced.
UK	2.2 (metal windows) 2.0 (non-metal windows)	Any window which is being replaced.
Netherlands	1.1 (glass)	Not a regulation as such, but a grant of 60 Guilders/m ² (27 Euros/m ²) is given for installing double glazed units of U1.1

Existing National Purchase Specifications

Femp

Table 7 summarises FEMP recommendations for purchasing energy efficient windows. The recommendation considers the country to be divided into just three three climate zones

A quick comparison with Table 1 shows that FEMP recommendations are less stringent than the PROST recommendations for colder climates. However the FEMP recommendations are also less stringent than the current common European building practices in cold mainly northern areas of Europe (see Table 5 above). For example standard requirements for Austria, Denmark, Norway, Russia, (and Sweden) are more stringent than the PA specific requirements defined by FEMP.

The PROST and FEMP requirements equate roughly for cooling load dominated climates; though the former is still more stringent than the latter. This might be justified, if needs be, by noting that the economic savings from efficient technologies are greater in Europe than in the US, in consequence of the higher energy prices.

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Table 7. FEMP recommendations for purchasing Energy-Efficient Residential Windows (translated to S.I. units)

	Recommended		Best Available	
	SHGC	U-factor W/m ² -K	SHGC	U-factor W/m ² -K
Heating		1.96		0.84
Heating and Cooling	0.55	2.24	0.2	0.84
Cooling	0.4	4.2	0.2	0.84

City of Frankfurt am Main

All new exterior windows in heated zones must be installed with double-pane low-energy glazing ($k = 1.5 \text{ W/m}^2\text{K}$).

Which in relation to heat loss equates closely with the PROST specification ($1.6 \text{ W/m}^2\text{K}$). The PROST specification is more complete in that also takes into consideration reduction in cooling loads.

Further Analysis

The economics of using Low-E and Spectrally Selective glazing is highly location (building) specific. As the discussion recalls above no cross country structured analysis has yet been completed which allows “typical” energy and economic savings to be identified in European. In the absence of “typical” savings, the present specification is based on a general but maybe not yet completely demonstrated premise that the use of advanced glazing is always cost effective.

A rational way to develop “typical” saving figures could be to categorise the very large number of building types in Europe as a representative sample set based on period of construction (according to the building codes in force when the buildings were constructed) and according to type of use (for example school, hospital or office, etc). Then determine building energy performance of this (not small) sample set of buildings considering :

- the different types of glazing and windows (which themselves would require classification)
- in a set of representative climate zones

This represents a significant amount of work; Italy alone, defines 6 climate zones for the purpose of heating system design. In each of these it would be necessary to check the performance of the complete set of (Italian) building types when operated with the different window classes. The operation would be repeated for all other EU countries.

Though theoretically possible it probably is not justified. As noted above, in mature markets the marginal cost of advanced glazing can be minimal (for example 0,3% of a new dwelling). The purchase of advanced glazing by the Public Administration across Europe, in line with this present specification, will do much to mature the market across Europe. With such marginal price premiums, Low-E and Spectrally Selective Glazing will indeed always prove cost effective, though it might prove difficult to determine by what degree.

Appendix 4

Recommendations for minimum performance standards for new and refurbished buildings in the public sector

Recommendations for Minimum Performance Standards for New and Refurbished Buildings in the Public Sector

1 Summary

Table 1 . Recommended Minimum Performance Standards (maximum delivered energy)for space heating, hot water and space ventilation in new and restructured office space

	<i>MJ/m²/year</i>	<i>kWh/m²/year</i>
Existing Buildings	250	70
New Buildings	145	40

Table 1 identifies the recommended maximum level of :
delivered thermal energy consumption to provide:

- hot water
- space heating

and delivered electrical energy for

- space ventilation.

in public sector **office space** in all EU Member States. The limits consider that delivered electrical energy is multiplied by 2.5.

1.1 Recommendations/Actions

Member States should :

Introduce a recommendation or requirement for Minimum Performance Standards specific to the public sector, as set out in Table 1.

Ensure that present and future national Energy Performance Standard methodologies cover sufficient technologies (both depth of analysis and range of solutions) to allow any Minimum Performance Standards specific to the Public Sector defined in Table 1 to be met.

Implement the requirements in line with the deadline for national implementation of the EU Buildings Directive (most likely by January 2006).

Prepare for the effective application of the Minimum Performance Standards, for example by:

- ensuring the limits can be met within the terms of national Energy Performance Standard methodologies
- communicating in advance the requirements to the public sector
- promoting integrated building design

Seek synergy between the processes of introducing national and public specific Minimum Performance Standards (for example in the development of communication programmes).

Define public sector specific Minimum Performance Standards at a level which ensures the greatest long term economic savings for the public sector.

Periodically review and update Performance Standards , at least in line with frequency set out in the the EU Buildings Directive (i.e., at least every five years).

Significant experience shows that the limits (the Minimum Performance Standards) reported in Table 1 can be achieved cost effectively whilst maintaining high levels of space comfort in buildings. In many Member States the limits represent a notable improvement, (up to 120%), on those limits derived from existing building codes. In a few cases the limit actually equates closely with those currently imposed by existing Member States building codes. Where existing limits are already restrictive (compared to the average EU condition), the Member States should nevertheless aim to introduce tighter requirements for public sector building stock (say a 20% improvement).

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However though the above limits are cost effective, a number of issues need to be addressed before any obligation could be placed on the public sector in this sense.

The following analysis considers the issues at stake, including restrictions, opportunities, and synergies presented by the forthcoming EU Directive "on the energy performance of buildings" (the *EU Buildings Directive*). The text explains the choice of limits and the importance of the recommendations/actions listed above.

2 The Need for Public Sector Minimum Performance Standards

Energy Performance Standards represent the latest stage in the evolution of building regulations over the last thirty years in Europe (see the Section 7 below). A recent survey conducted by the ENPER-TEBUC project (ENPER-TEBUC, 2000) shows that 17 of 19 Member and Candidate States currently have energy performance regulations.

The EU Buildings Directive, to be introduced by the end of 2002/early 2003 will require the *energy performance of buildings to be expressed in a transparent and simple manner* in all Member States by 2006.

Energy Performance Standards offer a significant advantage compared to other methods which aim to improve building energy efficiency. Briefly:

For building owners and users :

Performance Standards provide a clear measure of building energy performance which can usually be readily translated into running costs

For architect and designers,

Performance Standards provide creative freedom of choice in finding the optimal mix of:

- active technologies: for example artificial lighting systems
- passive solutions: for example spectrally selective glazing and window shading to provide summer cooling.

Thus the use of Performance Standards by the public sector is both auspicious and perfectly in line with current trends and future requirements.

The present recommendation however supposes that the public sector go further than adopt Performance Standards, but:

- impose consumption limits inferior to the those limits otherwise imposed by national building regulations
- impose limits on new and all refurbished building stock, independent of building size.

This recommendation responds to two objectives:

- i) that the public sector fulfils its general societal obligation to lead on issues of common good (for example CO₂ reduction, and in general pollution abatement) and specifically in relation to the forthcoming EU Buildings Directive *to set an example*.
- ii) that the Public Sector optimises its investments. As noted the Minimum Performance Standards identified in Table 1, are cost effective; buildings consuming more than the limits identified in Table 1 are in effect wasting public funds.

3 Defining Standards

Minimum Performance Standards can only be defined for:

1. an agreed level of indoor climate conditions

For example in terms of indoor air temperature, mean radiant temperature, their allowed daily and seasonal variations, the frequency of air replacement.

2. a precise methodology for determining building energy consumption

Respect of standards is determined by calculating energy consumption of a building according to a defined methodology, not by actual on site measurement ex-post. Methodologies consider for example the influence of thermal insulation, heating and lighting systems, occupancy and solar gains on building energy consumption.

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Defining acceptable comfort standards and methodologies at national level is a non-trivial exercise; in essence the definition of building codes. Further defining comfort standards for the Public Sector across EU, which at the same time respected all national requirements is clearly beyond the scope of this project.

Even proposing the direct uptake of existing Energy Performance Standards, with defined methodologies and comfort levels, such as the Swiss MINERGIE standard (see section 6.1), would require the requirements inherent to this programme to be compared for compliance with existing building codes in the 15 MS, which are themselves in a state of flux, (see later).

Even supposing that there were sufficient resources to develop an Energy Performance Standard, specific to the public sector across Europe, which being sufficiently stringent also respected all present and near future national building codes in terms limits to comfort and energy consumption, this would lead to a state of confusion; with public administrations required to show compliance to two sets of standards.

The definition of Minimum Performance Standards specific to the Public Sector can therefore really only feasibly be developed at national level, in respect of the Energy Performance Standards, (in terms of methodology and comfort levels), already, or soon to be in place, (at the latest by 2006).

This might suggest that the limits reported in Table 1 are of little value, since the essential elements of methodology and space comfort are missing.

However each national methodology though differing, should ultimately provide an estimate of actual building consumption. (Though methodologies are inevitably a compromise between simplicity of use and accuracy in predicting the real energy consumption of a building).

Further though comfort standards do vary to some degree across Europe it is reasonable to assume that they suppose more or less comparable levels; for example similar indoor temperatures, air changes per hour.

Thus Minimum Performance Standards should be more or less "portable" across Energy Performance Standard regimes. That is, limits to consumption defined in one country can be meaningful in others. It is probable that integration into a national Energy Performance Standard regime might require a slight adjustment of the limit; for example higher comfort levels practised in a particular Member State might require the limit to be increased.

Accepting that the actual limits can be integrated, does not negate the obvious need to transpose the index type reported in Table 1 (MJ/m²/year of delivered energy) to the performance indicator type in place (or to be in place) in each member state (for example kWh/m²/year of delivered energy, MJ/m²/year of primary energy, or indexed scale). However Performance Indexes, what ever their nature, represent only a means of conveying information and ultimately the final energy consumption of a building should be independent of index type.

In principle the limits reported in Table 1 should thus be applicable in all Member States. However there is one potential limit to application. As noted above, the respect of standards is determined by calculating energy consumption of a building according to a defined methodology, not by actual on site measurement ex-poste. To construct energy efficient buildings, methodologies need to cover and give sufficient weight to passive solutions; for example thermal insulation, energy solar gains, heat exchangers, ground cooling/preheating, natural ventilation, etc.

The Energy Performance Standard methodologies in each Member States therefore need to cover sufficient passive technologies (both in depth of analysis and the range of solutions) to allow the Minimum Performance Standards listed in Table 1 to be met. The Energy Performance Standards methodologies in place or under development (in light of the EU Buildings Directive) are however designed in order that national, not the here proposed stricter public sector specific, Minimum Performance Standards can be met. It may prove necessary therefore that the public sector work with national standards organisations in order to ensure methodologies are sufficiently developed in order that public sector specific limits can be met.

Recommendations/Actions

Member States should ensure that present and future national Energy Performance Standard methodologies cover sufficient passive technologies (both in terms of depth of analysis and the range of solutions allowed) to allow the Minimum Performance Standards specific to the Public Sector defined in Table 1 to be met.

4 Steps to Implementation

The proceeding discussion proposes that Minimum Performance Standards specific to the public sector are defined within the context of national Energy Performance Standards.

Many states already have some form of Energy Performance regulation. As noted above, a recent survey conducted within the ENPER-TEBUC project already shows such regulations in place in 17 of 19 Member and Candidate States, though these may not comply completely with the terms of the EU Buildings Directive (for example on the issue of integrating solar systems).

However in the worse case the EU Buildings Directive requires that Member States adopt a compliant Energy Performance Standard at the latest by 2006.

It does not seem feasible to promote an alternate Energy Performance Standard specific to the public sector in the intervening period. The adoption of an Energy Performance Standard for the public sector would require:

- Legislation of the requirement at EU or national level
- Definition of the Energy Performance Standard specific to the public sector at EU Level
- Promotion of the Standard at national level
- Uptake of the Standard at national level

Even assuming that this could all be achieved in two years from the present date (end of 2002) this would lead to a maximum period of implementation of say one year before being superseded by national standards in 2006.

Also this does not consider that some Member States, for example the UK and the Netherlands, have recently introduced Energy Performance Standards which already satisfy the requirements of the EU Buildings Directive and therefore would not implement a separate EU public sector specific Energy Performance Standard.

In consequence the most feasible solution is that the Minimum Performance Standards defined in Table 1 are integrated into current, or future, national Energy Performance Standards, on a time scale which equates with the deadline for implementation of the EU Buildings Directive (most likely January 2006).

From this date all public sector building stock would need to be built in line with the Minimum Performance Standards reported in Table 1, (suitably integrated in national Energy Performance Standards). Obviously those countries with Energy Performance Standards already in place could anticipate the 2006 deadline. However even here it would be necessary to ensure that methodologies defined within existing national Energy Performance Standards were sufficiently well developed in order that the strict values reported in Table 1 could be met (see previous section).

The most efficacious route to ensuring that the public sector introduce Minimum Performance Standards concurrently with implementation of the EU Buildings Directive, and thus at the latest by January 2006 would be for the the EU to make an explicit statement in this sense, either :

- Within the very same Buildings Directive. This represents the most logical path to introducing Minimum Performance Standards for the public sector, however the current (final) draft currently makes no requirement in this sense.
- Alternatively within a specific EU Directive for Energy Efficiency in the Public Sector. However even supposing that such a Directive were currently planned, it is unlikely that implementation time scale would be compatible with a 2006 deadline for introducing public sector specific standards. For the introduction of public sector specific standards would require a lead in time comparable to that for the introduction of general standards to be applied to the rest of the economy. This would in effect require that such, for the moment hypothetical, legislation be prepared and approved within say 2003 at the latest.

In light of which the only effective means to introducing Minimum Performance Standards by 2006 is for Member States to subscribe to the requirement as currently recalled in the EU Building Directive and *set an example by taking environmental and energy considerations into account* (Premise 12), and autonomously introduce the requirement for public sector to meet specific Minimum Performance Standards concurrently with the date of national implementation of the EU Building Directive.

The Minimum Performance Standards reported in Table 1 represent a feasible limit, which could be applied across Europe (see Section 6), and Member States should work to implement this limit within the context of the national Energy Performance Standards on the basis of this present recommendation and the implementation of the Buildings Directive.

Recommendations/Actions

Member states should:

Introduce a requirement for Minimum Performance Standards specific to the public sector, as set out in Table 1.

Implement the requirements in line with the deadline for national implementation of the EU Buildings Directive (most likely by January 2006).

Prepare for the effective application of the Minimum Performance Standards, for example by:

- ensuring the limits can be met within national methodologies
- communicating in advance the requirements to the public sector
- promoting integrated building design, including the diffusion of the necessary design tools

Seek synergy between the processes of introducing national and public specific Minimum Performance Standards (for example in the development of communication programmes).

5 Public Sector Performance Standards and the European Directive on the energy performance of buildings

The EU Directive for Energy performance of buildings currently under discussion aims to introduce Performance Standards for buildings in all sectors of the economy by January 2006.

5.1 Compatibility of Requirements

The EU directive is a framework directive which requires, summarily:

1. that the energy performance of a building should be expressed in a transparent and simple manner.
2. new buildings which are intended to be used regularly must meet minimum energy performance standards
3. when buildings with a total useful floor area over 1000 m² undergo a major renovation, their energy performance is to be upgraded in order to meet the minimum requirements ... (the requirement will be evaluated within five years and a decision made as to whether to extend the measure to buildings of less than 1000 m²).

On these and other points public sector specific Minimum Performance Standards are completely in line with the requirements of the (draft) Directive.

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By:

- applying more restrictive Minimum Performance Standards to its own building stock
- introducing Minimum Performance Standards to restructured buildings, irrespective of size

the Public Sector responds to the requirement laid in the Directive for

"Public authority buildings and buildings frequently visited by the public should (to) set an example by taking environmental and energy considerations into account"

5.2 Integration of Requirements

The introduction of the EU Buildings Directive will instigate, or is concurrent with, a period of renewal of building codes across Europe; 15 European Member and Candidate countries have introduced new regulations or changed old ones since 2000 or at least plan to introduce new or changed regulations before 2005.

The more stringent requirements specific to the public sector need to be feasible within Member State Energy Performance Standards. Namely achieving the limits (listed in Table 1) will require that the calculation methodology adopted by each Member State considers and importantly gives sufficient weight to passive solutions (for example, use of shading, natural ventilation, day lighting, heat exchangers).

There is a general trend in this direction, and the (Draft) EU Buildings Directive requires that member states define methodologies for determining the energy performance of buildings which integrate:

- thermal insulation (of building shell and installations)

and take account of the positive influence provided by:

- solar systems and other heating and electricity systems based on renewable energy sources

However achieving higher standards in the public sector might well require that this methodology is developed further than might otherwise be required for national performance standards.

Thus in the case that Member States are in the process of developing Energy Performance Standards there are obvious synergies for this process to consider the specific requirements placed upon the public sector. In the case that Member States have already introduced Energy Performance Standards (for example the UK and the Netherlands) the standards need to be checked for the feasibility of achieving the strict requirements placed upon the Public Sector.

Recommendations/Actions

Member States should invite national standards bodies to ensure Energy Performance Standards methodologies are sufficiently complete to allow the strict requirements placed upon the public sector to be met and seek synergies where the national standards are in course of renewal.

5.3 Defining National and Public Sector Minimum Performance Standards

The development of Energy Performance Standards, (namely the renewal of building codes) generally includes a period of consultation with the many parties affected by their introduction; the construction industry, product supply and building design. National Minimum Performance Standards will likely balance the many requirements, considering both the technical and economic savings potentials as well as the practical problems of implementation by industry; for example considering the level of technical preparation of designers across the country. Ultimately the choice of the level at which to set a national Minimum Performance Standard is a political decision.

However Minimum Performance Standards specific to the public sector need not be limited by practical problems of implementation at national level, and should aim to achieve the greatest long term economic benefit for the public sector. This can be best achieved by maintaining the development of national Minimum Performance Standards and the development of public sector specific Minimum Performance Standards separate.

Recommendations/Actions

Member States should define public sector specific Minimum Performance Standards at a level which ensures the largest long term economic savings for the public sector.

6 Level of Standard

An analysis conducted by the Fraunhofer Institute in 1999 (Eichhammer, 1999 ?) showed that the then in force building regulations resulted in delivered heating energy consumption in new residential buildings of between roughly 40 to 100 kWh/m²/year, depending on the country, (Table 4).

As noted elsewhere, building codes are however under a period of renewal across Europe. 15 European Member and Candidate countries have introduced new regulations or changed old ones since 2000 or at least plan to introduce new or changed regulations before 2005. Thus it is not known how well the figures reported in Table 4 reflect present limits.

Limited data (Table 3) from the more recent TEBUC study¹ shows a similar range of unit energy consumption across Europe (from 48 to 100 kWh/m²/year), though the limits applied by each state vary with respect to the previous study.

Information on energy consumption in existing commercial building stock is limited (Table 5).

For some Member States (for example Belgium and Italy) the public sector specific Minimum Performance Standards for new buildings defined in Table 1 represent a significant improvement over existing regulations. In others, for example Denmark the proposed public sector specific requirements equate more or less with existing national requirements.

The Minimum Standard for refurbished buildings defined in Table 1:

- brings a requirement to refurbished buildings, which otherwise in most Member States is missing (only 40% of Member States currently have any form of requirement for existing buildings)
- represent a significant improvement to the energy consumption of existing building stock, currently in the range of 120 to over 200 kWh/m²/year (Table 5).

One way to define the upper limit for building energy consumption is to develop a least lifecycle cost curve for the different solutions which can be adopted to provide required building service levels (air and wall temperature, air change frequency).

However though for many products (for example refrigerators and ovens) a least cost curve is an objective tool with which to identify the most economical level of energy efficiency, the approach becomes more difficult for buildings in view of their extremely wide diversity and the range of solutions which can be adopted. The situation is further complicated when we consider low energy buildings, where improved efficiency is not achieved through the addition of hardware (which has a readily retrievable list price), but rather through improved design, which in many cases actually avoids the use of hardware. In this case to develop a least cost curve would require information of the marginal cost of designing and implementing a passive solution with respect to designing and implementing active solutions. Though this no doubt can be achieved it has proved beyond the resources of this study.

Instead the limits in Table 1 are defined by considering the cost effectiveness and the feasibility of achieving energy efficient buildings based on international experience. The most significant experience probably comes from Denmark, where national building codes impose upper limits on thermal energy consumption which equate closely with the limits defined in Table 1, (see Table 3 and Table 4). Assuming similar energy prices across Europe, then cost effective measures in Denmark should prove equally cost effective elsewhere.

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Otherwise the Swiss MINERGIE programme and dispersed experience from Germany in recent years, both considered below in more detail, show that the limits defined in Table 1 :

- can be realised in functional buildings
- can be achieved when refurbishing
- can be achieved cost effectively

Table 2 provides a summary of existing target values and requirements applied in a number of Member States which go beyond the national building codes.

The proposed Minimum Performance Standards reported in Table 1 equate with the Swiss MINERGIE standard prior to its recent update (more restrictive from 2002), the requirements of the provincial administration of Bolzano, in the North of Italy and the target values for commercial sector buildings set by the State of Hessen in Germany. These standards/requirements are in place in areas of Europe with some of the harsher winter conditions. Degree days¹ in Germany, and Bolzano are 3845 and 2791 respectively compared to say 1800, 1600, and 1738 in Portugal, Spain and Italy (cross country average).

If high standards can be achieved in such conditions, it is reasonable to suppose they can be achieved at lower cost in milder climates.

Slightly at odds, apparently, with the Minimum Performance Standards defined in Table 1 are the good practice benchmark values proposed by the UK DETR Good Practice Programme. However though it is not entirely clear it would appear that the DETR target values (Table 2) relate principally to existing stock, and as such equate with the values reported in Table 1. The DETR Good Practice Programme in fact notes that *new designs should improve upon the good practice benchmarks* though the programme refrains from defining to what degree.

Otherwise there is much dispersed international experience of developing low energy buildings, in part reviewed below. Some of this experience would indicate that a much lower Minimum Standard than defined in Table 1 (say < 5 kW/m²/year for new buildings) could still prove cost effective (see the section RMI below).

¹Basis 20°C average

Table 2 Existing Good Practice, Target and Recommended Values from across Europe for thermal service provision. (Key : GP = Good Practice, Req. = Required, Tgt. =target, New =New Buildings, Old = Old Buildings). Units in kWh/m²/year

	VDI 3807	Minergie (Heating, Hot Water + Ventilation)				HUMEB		Bolzano		DETR (heating + hot water)	
	GP	Req. New	Old	From 2002 Req. New	Old	Req.	Tgt.	Req. New	Old		GP
homes		45	90								
schools	55			40	70	75	50				
sports facilities	65			25	50	60	40				
kindergardens	65										
office buildings	65	40	70	35	65	75	50	40	80		
										naturally ventilated cellular	79
										naturally ventilated open plan	79
										air conditioned, standard	97
										air conditioned prestige	107
indoor pools *	1,800										
shops				35	60	75	50				
restaurants				45	85						
meeting halls				40	80						
hospitals				75	110						
industry				20	50						
warehouses				20	45	60	40				

*) specific to pool surface area

Sources:

	Country of Application	Controlling Agency	Description
DETR (1998)	UK	Department of the Environment; Transport and the Regions	Best Practice Programme : Energy Use in Offices
MINERGIE	Switzerland	Secretriari MINERGIE, BERNE	MINERGIE standard
VDI 3807	Germany	1994: VDI-Richtlinie 3807: Energieverbrauchskennwerte für Gebäude; Heizenergie- und Stromverbrauchskennwerte, Grundlagen, Blatt 1, Heizenergie- und Stromverbrauchskennwerte, Blatt 2, Düsseldorf.	Guideline
HUMEB (1996)	Germany	Energie im Hochbau, Leitfaden energiebewußte Gebäudeplanung	State of Hessen Guidelines for the Residential and Commercial Sector
Bolzano	Italy	Provincia di Bolzano	Requirement for building stock owned by the provincial administration. (Delibera 3574 of the 29 July 1996)

6.1 The MINERGIE Standard , Switzerland

MINERGIE is a quality label for new and refurbished buildings. It is a trade name mutually supported by the Swiss Confederation, the Swiss Cantons along with Trade and Industry and has been registered to prevent misuse.

1.800 buildings have been certified by MINERGIE, composed of 680.000 m² of office space and 700.000 m² of private dwellings.

MINERGIE is based on three basic requirements:

- building specific energy consumption
- building comfort
- cost

Specific energy consumption is used as the main indicator to quantify the required building quality. In this way, a reliable assessment can be assured. Only the final energy consumed is relevant.

The upper limits for energy consumption for covering heating, hot water and space ventilation are listed in Table 2. Until recently MINERGIE defined two levels of acceptable energy consumption (for new and refurbished buildings) for two categories of building (dwellings and commercial). In 2002 articulation was increased with commercial buildings split into sub categories (restaurants, meeting halls, hospitals etc.)

For the commercial sector MINERGIE also defines limits for energy use of lighting systems. The limit is based on the SIA 380/4 building code produced by the Swiss Association of Architects and Engineers. However the SIA 380/4 is articulated on the hours of use, the index and the type of each space in the building, (for example whether an office, gym, corridor, etc.).

Comfort is the central theme to MINERGIE, and the standard **requires** active controlled ventilation of building space.

The third important requirement of MINERGIE is that the additional investment cost of the efficient solutions amounts to no more than 10% of the cost of "standard" alternative.

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The MINERGIE Standard is now widely accepted. There are many reasons for this, the most important: builders and planners - in other words architects and engineers - have complete freedom both in their design and choice of materials and also in their choice of internal and external building structures.

MINERGIE is supported by comprehensive documentation and a well structured WEB database.



Illustration 1. Office block achieving the MINERGIE standard in Zurich.

6.2 Low-energy Office Building Demonstration Projects - from Germany

In Germany, a number of low energy (heating energy consumption of 40 kWh/m²/year or below) or even passive office buildings (heating energy consumption of 15 kWh/m²/year or below) have been constructed in recent years. Examples are:

- The building for the central administration of Deutsche Bahn Netz AG in Hamm, brought into operation in 1999, needs less than 40 kWh/m²/year (BINE, 2000).
- The Annex of the Wuppertal Institute, in operation since 1998, has a heating energy demand of 35 kWh/m²/year.
- The passive office building of the Lamparter company in Weilheim a. d. Teck, also finished in 1999, uses 51 % less heating energy than required by the building code. Furthermore, electricity use for lighting is only 5 kWh/m²/year, and for artificial ventilation 6 kWh/m²/year (BINE, 2000)
- The passive office building of the solar energy system manufacturer Wagner&Co. in C?lbe in operation since late 1998 only 12.5 kWh/m²/year for heating (actually measured). This is supplied from a small-scale CHP plant, and a solar thermal system with a large buffer tank integrated in the building. Electricity need for ventilation is 6 kWh/m²/year (BINE, 2000)

BINE concludes from these examples, that for new office buildings, **primary energy demand** for heating, lighting, ventilation, possibly cooling, and other installed systems together should not exceed 100 kWh/m²/year and proposes a target value of 75 kWh/m²/year.

A primary energy limit of 100 kWh/m²/year has also been set for the new annex building (Ostarkade) of the Kreditanstalt für Wiederaufbau (KfW, the investment bank of the federal government) in Frankfurt am Main (www.solarbau.de). This will mean an energy saving of 70 % compared to current standards for new complex office buildings (350 kWh/m²/year), and 80 % compared to existing complex office buildings in Frankfurt (www.energiereferat.stadt-frankfurt.de).

6.3 Rocky Mountain Institute

The experience of the Rocky Mountain Institute (RMI), Colorado, USA is perhaps singular, but nevertheless a concrete example of developing extremely energy efficient cost effective **office space**.

The RMI, which covers an area 450 m², has no heating system in the usual sense, but is largely heated by passive solar gain through the windows and a central glazed area (greenhouse). The greenhouse serves as the building's main heat generator: sunlight enters vertical and overhead glazings and transfers both radiant heat and warm air to the adjacent "wings" of the building, with excess heat vented. Additional energy for heating is stored in the arch, the greenhouse earth, the inner walls, the floor slab, and the soil beneath. Fresh air arrives through a heat exchanger which transfers 75% of the warm air which leaves.

The walls are 40 cm thick, consisting of two 15-cm courses of masonry sandwiching four inches 10 cm of Freon-filled polyurethane foam (non-CFC foam was not available at the time of construction).

Much of the building's thermal performance is due to its advanced windows, which were used here commercially for the first time. Virtually all are made of argon-filled Heat Mirror². They lose only 19 percent as much heat as a single pane of glass, but let in three-quarters of the visible light and half of the total solar energy.

Two wood stoves are used for backup heating in especially cold or cloudy weather.

Total delivered energy consumption for heating can be estimated to be in the order of **3 (THREE) kWh/m²/year**, and this as noted provided by a renewable source (biomass).



Illustration 2. Views of the Rocky Mountain Institute, Colorado, USA.

This is achieved in a particularly harsh climate. The building is at an altitude of 2200 m where winter temperatures can fall to -44°C and in only in 52 days a year does the temperature exceed 0°C. In winter cloud cover has been as long as 39 consecutive days.

The net additional cost of the energy saving features (after subtracting the savings from not needing a furnace and ductwork) was about \$6,000, or \$13.50 per square meter, or just over one percent extra. Compared with normal local building practice and with the cheapest conventional fuels (firewood and propane), the building produces an average of about \$6 worth of saved energy per day. Annual savings thus amount to about \$2,000 a year, which means a roughly three year pay-back. The building was built in 1983-84; improvements in technology would mean that if built today the economics would be better.

The technologies and design principles responsible for this performance can be cost-effectively used in tract houses, custom homes, or larger buildings in almost any climate and architectural style.

²Heat Mirror, is a trademark of the US Southwall Corporation

7 Further Considerations and Background Information

7.1 Current Energy Consumption in New Buildings

Table 3. Thermal Performance Standard of new buildings from the SAVE II ENPER-TEBUC study (WEBER 2002)

	(kWh/m ² /year)	(MJ/m ² /year)
Denmark	48	173
Sweden	75	270
Netherlands	91	328
Germany	102	367
France	105	378

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Table 4. Thermal Performance of new homes based on building regulations in place in 1999, from an analysis conducted by the Fraunhofer Institute. In 1999 only England, France and Italy used fully integrative methodologies. In other cases unit consumption was determined by applying the required unit or average shell to a model house considering national climatic conditions.

The values are indicative of consumption in the tertiary sector. Units in kWh/m²/year

		Denmark	Sweden	Lux.	Netherlands	France	Greece	Germany	UK	Spain	Austria	Portugal	Ireland	Finland	Italy	Belgium
Elemental Approach	(kWh/m ³ /a)	13,36	14,31	18,97	20,6		18,17	18,95	21,99		25,39	26,51	22,38	28,21		33,11
Integrative Approach	(kWh/m ³ /a)				19,12	20	22,6	23,2	21,62	24,89			31,01		28,95	31,43
Elemental Approach	(kWh/m ² /a)	41,82	44,79	59,38	64,48		56,87	59,31	68,83		79,47	82,98	70,05	88,3		103,63
Integrative Approach	(kWh/m ² /a)				59,85	62,6	70,74	72,62	67,67	77,91			97,06		90,61	98,38
Summary	(kWh/m ² /a)	42	45	59	62	63	64	66	68	78	79	83	84	88	91	101
	(MJ/m ² /a)	151	161	214	224	225	230	237	246	280	286	299	301	318	326	364

7.2 Current Energy Consumption in Existing Buildings

Table 5. Typical values of delivered energy consumption for space heating (and hot water supply) across Europe. From a number of sources. Units: kWh/m²/year

	ISI (1998)	Ages (2000)	Cadett						VDI 3807 Avg.	DETR (1998)	Typ.
			AU	BE	GE	NL	CH	UK			
schools		primary Schools	158						90		
sports facilities		gymnasiums 1000-2000	187						140		
kindergardens		9-year elementary school	150						120		
office buildings	164	federal and state ministries	130						110		
		administrative buildings	143					naturally ventilated cellular		151	
		administrative buildings normal	120					naturally ventilated open plan		151	
								air conditioned, standard	178		
								air conditioned prestige	201		
indoor pools *		Indoor Public Fun Baths	3.586						3,9		
meeting halls		Youth meeting centres	218								
hospitals				230	270	300	330	190	500		

*) specific to pool surface area

Sources:

DETR (1998)	UK	Department of the Environment; Transport and the Regions
Caddet	Caddet , IEA	Energy Efficiency in Hospitals
AGES (2000)	Germany	Ages 2000: Verbrauchskennwerte 1999 - Energie- und Wasserverbrauchskennwerte von Gebäuden in der Bundesrepublik Deutschland. Forschungsbericht der ages GmbH, Münster.
ISI (1998)	Germany	ISI (Fraunhofer-Institut für Systemtechnik und Innovationsforschung) et al. 1998: Energieverbrauch und Energieeinsparung in Handel, Gewerbe und Dienstleistung, Schlussbericht zum Vorhaben "Strukturierung des Energieverbrauchs im Sektor Kleinverbraucher als Grundlage für die Aktivierung von Energieeinsparpotentialen" für die Deutsche Bundesstiftung Umwelt, Karlsruhe
VDI 3807	Germany	1994: VDI-Richtlinie 3807: Energieverbrauchskennwerte für Gebäude; Heizenergie- und Stromverbrauchskennwerte, Grundlagen, Blatt 1, Heizenergie- und Stromverbrauchskennwerte, Blatt 2, Düsseldorf.

7.3 Cross Country Variation of Minimum Performance Standards

Table 1 proposes a common Minimum Standard for public sector buildings across Europe. A more rational solution would be for Minimum Performance Standards to vary in proportion (though necessarily direct) to degree days; with harsher northern countries imposing lower limits (i.e. allowing for higher energy consumption) than southern states.

However the situation in Europe today is actually reversed with building regulations in northern states leading to lower annual unit consumption than in southern states (for example 40 kWh/m²/year in Denmark compared to 100 kWh/m²/year in Italy).

Thus, though it seems unreasonable to suppose that the actual situation might be completely reversed in the near term so as to arrive at the rational solution, with southern states (Italy, Greece and Portugal) imposing (and achieving) more stringent performance limits than northern countries (Denmark), it does however seem reasonable to propose that public sector buildings in the southern countries are at least no worse than those in the north.

Recommendation/Action

Variation in Minimum Performance Standards should be proportionate (though not necessarily directly) to degree days, with more severe limits for milder climates. For simplicity of actuation a standard cross country value could also be allowed.

7.4 Index Type

Minimum Performance Standards in Table 1 are in terms of delivered kWh/ m²/year and MJ/m²/year of delivered (useful) energy, for two reasons:

- currently the larger part of building codes in EU MS define Performance Standards in terms of delivered useful energy. (Precisely 7 MS use delivered Energy, 5 MS Primary Energy and 2 MS Carbon Dioxide Emissions).
- there is considerable amount of information on building energy use available in terms of delivered energy

Otherwise the current recommendation does not intend to express a preference for a MJ/m²/year index.

7.5 Development of Building Codes

The **component approach** is the approach with the lowest level of integration and only considers the heat transmission through the building shell. It divides the building shell into its individual components (e.g. outer walls, roof, basement ceiling, windows, door, etc.) and states maximum heat transmission value for each of these components separately.

Giving an **average transmission** through the building shell represents a preliminary level of integration, which allows more flexibility. Instead of standardising each building component, it is sufficient to give a single value for the building

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shell. The result is greater flexibility as a higher transmission through one component (e.g. the walls) can be compensated for the better values for other components (e.g. the roof, the windows).

The next level of integration indicates maximum values for heating demand of the building, which is a more systematic approach than the previous two. With this approach not just the building shell is optimised, but a reduction of the energy demand could be achieved via improved ventilation with lower heat losses or an increased use of passive solar energy through relevant architectural design.

The final stage of integration (**fully integrated approach**) covers heating and cooling supply as well as heating and cooling demand and consequently results in the integration of the insulation regulation with any heating and possibly cooling system regulation.

Fully integrated design procedures have been introduced in England, France, Germany, Italy, and the Netherlands, though most do still not take account of summer cooling strategies.

The main advantage of integrated design is that it is **goal orientated**; the performance of the building is characterised in terms of actual building final energy us (though this maybe in some way parameterised).

Integrated approaches effectively reflect the state of the art of both technical solutions which can be installed (for example selective glazing) and the design tools which can evaluate their impact (software for building thermodynamic modelling).

7.6 More Information

MINERGIE :
Secretariat MINERGIE
Steinerstrasse 37
3000 Berne 16
www.minergie.ch

Sustainable Buildings
Voorbeeldprojecten
Novem
Postbus 17
6130 AA Sittard
www.novem.nl

8 References

ENPER-TEBUC, 2000. EU SAVE II Project "European collaboration in relation to Energy Performance Regulation for buildings and model code development. Towards a European Building Code"
Eichhammer, 1999 ?. "A Comparison of Thermal Building Regulations in the European Union", Wolfgang Eichhammer
BINE Informationsdienst, 2000: Energieeffiziente Bürogebäude, profiinfo II/00, Bonn
Weber, 2002. From Presentation at EnPer workshop, London September 2002, Universitat Stuggart, Institut fur Energiewirtschaft und Rationelle Energieanwendung,

Appendix 5

Summary of costs and benefits from
using electronic ballasts

(Printout of spreadsheet)

Usage				
			Ballast Type	
			Electromagnetic	Electronic
Annual use	(hours/year)	700	700	
Lifetime of system (luminaires)	(years)	10	10	
Installation Costs				
Purchase of ballasts	(Euro)	5,40	13,50	
Annual Costs				
Maintenance costs				
Average lamp life	(hours)	10 000	15 000	
Total no. of lamp replacements over system lifetime		0,7	0,466666667	
Total lamp costs over system lifetime	(Euro)	5,8968	3,93	
Average time to replace lamp	(min)	5	5	
Total labour costs over system lifetime	(Euro)	0,00	0,00	
Total maintenance cost for system over system lifetime	(Euro)	5,8968	3,93	
Average annual cost (in real values)	(Euro/year)	0,59	0,39	
Energy costs				
Total no. of kWh absorbed by system each year	(kWh/year)	64,4	49,7	
Annual cost (in real values)	(Euro/year)	6,44	4,97	
Power costs				
Total number of kW absorbed by lighting system	(kW)	0,092	0,071	
Factor of contemporaneity with peak load	(Euro)	1,00	1,00	

Appendix 6

Swiss regulations for proof of cooling demand

Swiss Regulation for proof of cooling demand

In Switzerland, installing an air-conditioning plant is subject to approval. The engaged engineering office has to submit a proof of cooling demand at the local building control authority. Requirements for the proof of demand are listed in the SIA¹ standard 382/3. The space or building at issue have to fulfil the following criteria:

- *Envelope*: insulation and air-tightness of the envelope must fulfil the limits of national and local building codes, e.g. minimal U-values of walls = 0.5, roof = 0.4, windows and frames = 1.8 W/m²K, maximal air infiltration rate = 0.5 h⁻¹.
- *Thermal inertia*: a minimal thermal inertia of 350 kg/m² (storage effective mass) is required. In the case of double ceilings, the thermal inertia of the upper ceiling may only be accounted for, if there are large openings (min. 15% of the surface) in the hanging ceiling.
- *Solar gains*: total energy transmission coefficient of windows (transmission + inward rejection of absorbed energy) must be below 0.15. For south, east and west windows this value can only be achieved with fixed or movable shading devices. This means that for the proof of cooling demand solar gains may

only be accounted for if there are external shading devices on south, east and west walls of the building under study.

- *Use*: through technical and operational measures, the space to be cooled has to be reduced to a minimum (concentration of load intensive equipment in separated rooms).
- *Internal gains*: the electrical load of lighting and office equipment should fulfil the limits given by SIA standards (see Table 2). If these standards are exceeded, detailed information sheets of the installed equipment (power in different modes, operation hours) have to be submitted to the authority to prove elevated internal gains. Cooling demand due to office appliances does not require any approval if the appliances fulfil the values given in Table 3.
- *Comfort*: the maximal indoor temperature in summer which is considered to provide an acceptable comfort level ranges from 22 to 28°C, with a relative air humidity of 30 - 65%. Other limits are valid for particular uses, as, e.g. warehouses for food and other delicate products, industry with special production conditions, etc.

Table 1: Limits for the energy consumption of office equipment; stand-by is corresponding with Swiss target values.

appliance	active	stand-by/sleep	off
PC	60 W	10 W	5 W
monitor	90 W	5 W	-
PC with monitor	150 W	15 W	5 W
printer, laser	190 W	2 W	1 W
printer, other	20 W	2 W	1 W
photocopier	1100 W	27 W + 3.23*cop./min.	1 W
fax, laser	80 W	2 W	-
fax, others	20 W	2 W	-

The demand for a cooling plant is approved by the authorities, if the internal heat gains are above the following limits:

Room without operable windows:	250 Wh/m ² for 12h day
	350 Wh/m ² for 24h day
Room with operable windows:	350 Wh/m ² for 12h day
	450 Wh/m ² for 24h day

¹ Association of Swiss Engineers and Architects

Under standard conditions (use, occupation, equipment), the internal cooling load of most building categories, including large offices, is usually below the limits given above (see Table 2). Exceptions are supermarkets, auditoriums, restaurants and kitchens, where a demand for air-conditioning occurs very often.

The cooling load has to be determined with the simulation tools DOE-2.1E or HELIOS, using standard libraries elaborated by the Swiss Agency for Material Testing (EMPA). The proof of cooling demand has to be submitted with the complete input data set which has been used for the simulation.

Table 2: Swiss limits for internal heat gains; if higher values occur, detailed inventories of the installed equipment and lighting system has to be submitted to the authorities together with the calculated proof of cooling demand.

	appliances			persons		lighting				refrigerators		total
	operation	power	daily	occupation	power	daily	power	daily	power	daily	daily	
		density	load		density	load	density	load	density	load	load ¹⁾	
	h	W/m ²	Wh/m ²	m ² /P	W/m ²	Wh/m ²	W/m ²	Wh/m ²	W/m ²	Wh/m ²	Wh/m ²	
single office, low load (1-2 pers)	12	3	24	15	5	41	10	81			146	
single office, medium load (1-2 pers)	12	7	57	15	5	41	10	81			178	
single office, high load (1-2 pers)	12	10	81	15	5	41	10	81			203	
group office, low load (3-6 pers)	12	4	25	12	6	38	10	108			171	
group office, medium load (3-6 pers)	12	8	50	12	6	38	10	108			196	
group office, high load (3-6 pers)	12	13	82	12	6	38	10	108			228	
large offices, low load (>6 pers)	12	5	27	10	7	38	10	108			173	
large offices, medium load (>6 pers)	12	10	54	10	7	38	10	108			200	
large offices, high load (>6 pers)	12	15	81	10	7	38	10	108			227	
meeting room	12	2	11	2.5	28	151	10	63			225	
ticket office	12	5	36	10	7	50	13	129			215	
grocery	12		0	8	9	57	10	108	5	54	219	
retail store, non-food	12		0	8	9	57	10	108			165	
supermarket, food *	12		0	5	14	88	16	173	-10	-108	153	
supermarket, non-food	12		0	5	14	88	16	173		0	261	
mall	12		0	3	23	166	16	173		0	338	
classroom	12		0	3	20	126	10	63		0	189	
auditorium	12	2	14	0.8	88	634	10	72		0	720	
canteen	12	1	5	1.2	58	157	6	43		0	205	
restaurant	12	1	9	1.2	58	157	9	97		0	263	
restaurant (high level)	12	1	10	2	35	95	14	151			256	
kitchen restaurant, average load	24	180	1134		10	90	10	108			1332	
kitchen restaurant, high load	24	250	2250		10	117	10	153			2520	
bedroom, clinic, medical care	24		0	15	5	108	6	32			140	
hotel room	24	2.5	54		7	63	10	36			153	
commercial storage											0	

Note.

1) bold figures: building categories eligible for the installation of a cooling plant

normal figures: under standard conditions (occupation, use) these building categories have an internal heat load below the limit for cooling plants

* Negative values derive from externally dissipated waste heat from refrigerators

Table 3: Energy label 96 standards and target values for office appliances.

	Energy label 1996		Target values 1996/97	
	Stand-by (W)	Off (W)	Stand-by (W)	Off (W)
telefax	6		2	-
<i>printers</i>				
laser, LED	16	3	2	1
others	6	3	2	1
Photocopiers	27+3,23.c*	1	27+3,23.c*	1
<i>multifunctional printers</i>				
A: fax/printer/photocopier	27+3,23.c*	1		
B: fax + printer interface				
laser, LED	16			
?others	6			
C: photocopier + printer interface	27+3,23.c*	1		
PC with monitors	30	5	15	5
PC without monitors	25	5	10	5
monitors	5	-	5	-

Appendix 7

German recommendations for municipal energy management

Unofficial translation of the recommendations from "Deutscher
Städtetag" (Association of German cities)

Energy Guidelines – Design Instructions

Rationale for an Energy Guideline

Many local authorities are today performing an active energy management. While this task is co-ordinated by the respective organisational unit, it is influencing the tasks of many employees within an administration. Energy guidelines enable a concise operation of the administration, pursuing the targets of energy saving and energy efficiency. An energy guideline offers the opportunity to bundle basic principles for design, operation, and energy management in one central regulation, which ideally should be decided upon by the City Council. Hence, energy guidelines do not mean general principles for dealing with energy issues, but a summary of concrete instructions for design and operation, as well as regulations of responsibilities.

The following text is meant to be a part of a blueprint guideline, which can be passed as it is by the municipality. Some of the contents were taken from earlier volumes of the Tips for Municipal Energy Management.

1. Preamble

The priority design principle for all municipal building projects is to minimise the total of investment costs and running costs over the lifetime of the building. The best way to achieve this target is to use the method of Integrated Building Design, i.e., a close interaction of all professions during the design phase.

The municipal energy guidelines complement existing laws, standards, and norms. They reflect the current state of the art and will have to be adapted if necessary. It is possible to deviate from the design standards, if there is a proof that the alternative solution is economically more advantageous.

These design standards have to be handed over to architects and engineers upon commissioning them. They have to be required to obey these standards.

2. Economic Analysis

In principle, all cost-effective measures shall be implemented. A measure will be cost-effective, if during the calculation lifetime¹ the saved energy and operation costs are lower than the necessary investment costs. The total of the levelised investment costs and the annual operating expenses has to be minimised. The following concrete tips are aiming at this target. If a measure is cost-effective in this sense, it shall be implemented in the short term.

In addition, it is conceivable to include environment costs resulting from energy use, e.g., in the form of a bonus for the CO₂ reduction of 50 €/tonne of CO₂², as practised in Munich, Frankfurt am Main, and Bremen.

3. Architecture

Compact buildings need little heating energy. Lobbies and corridors as well as auxiliary rooms, but also air volumes should be minimised. Buildings should primarily be designed for natural ventilation.

In all rooms, daylight should be used, workplaces have to be designed with regard to daylighting. In rooms, for which a lighting intensity of more than 300 lux is required, daylight quotients of more than 3 % according to DIN 5034 (explanation: this daylight quotient is the percentage of the exterior daylight intensity that reaches a point in the interior of a room), for corridors or similar at least 1 % have to be achieved.

¹ According to VDI standard 2067, volume 2

² according to GEMIS 4.1, Gesamtemissionsmodell integrierter Systeme, Land Hessen 1993

Light rooms with high reflecting efficiencies (of interior surfaces, the PROST team) need less electricity for artificial lighting. The following minimum reflecting efficiencies have to be achieved:

Ceiling 0,8; walls 0,5; floor 0,3³.

Window breast areas shall not be designed as windows in order to make it easier to achieve the requirements for summer heat protection according to DIN 4108 part 2. If windows go down to the floor, the U value of the window element must be lower than 0.9 W/m²K.

For main entrances, non-heated vestibules shall be built.

All window areas exposed to the sunlight will receive an exterior sun-shed with ventilation behind the blinds (light permeability $b < 0,2$ according to VDI 2078). It will in principle be automatically controlled, but with the possibility for manual over-ride. The sun-shed has to be designed so as to avoid the need for artificial lighting. This can be achieved, e.g., with exterior venetian blinds with a perforation in the upper part or impossible to shut completely.

4. Constructive Heat Protection

For all new buildings, both the primary energy demand and the average heat transmission H_T' have to be 20 % below the requirements of the federal building code (Energieeinsparverordnung – EnEV). Details have to be designed so as to achieve a supplement for heat bridges that is lower than 0.05 W/m²K. This can either be proven by individual calculation or by using details from the heat bridge catalogue. Air tightness has to be proven with a blower-door measurement. A limitation to representative parts of the building is conceivable. In that measurement, n_{50} values (i.e., the average of the values measured at an over-pressure and an under-pressure of 50 hPa produced by the blower door) of < 3 /hour in buildings without artificial ventilation, and < 1.5 /hour with artificial ventilation have to be achieved.



Figure 1: Low energy office building of the port utility of Frankfurt a.M. (Heating energy consumption = 35 kWh/m²a)

If existing buildings are refurbished, the following are maximum allowed U values:

Walls: 0.3 W/m²K, roof: 0.2 W/m²K, ground floor: 0.4 W/m²K, windows: 1.4 W/m²K. For windows, a spacer with improved thermal resistance has to be chosen. Window bars have to be avoided.

Exceptions will be possible, if technical reasons or architectural reasons (for building monuments) prevent this. Exceptions have to be co-ordinated with the energy management unit.

5. Heating Systems

For the heat supply to municipal facilities, systems using waste heat from cogeneration of heat and power or renewable energies have priority. District heat systems can fulfil this requirement. If this is not possible, the use of natural gas will be preferred.

For heating plants with a connected load above 300 kW, the cost-effectiveness of using wood or a small-scale CHP plant has to be examined. Pool water heating of

³ AMEV standard Lighting 2000

outdoor swimming pools has to be provided through a solar pool water heater. For objects with a high demand of sanitary hot water (e.g., sports facilities), the installation of a solar water heater has to be examined.

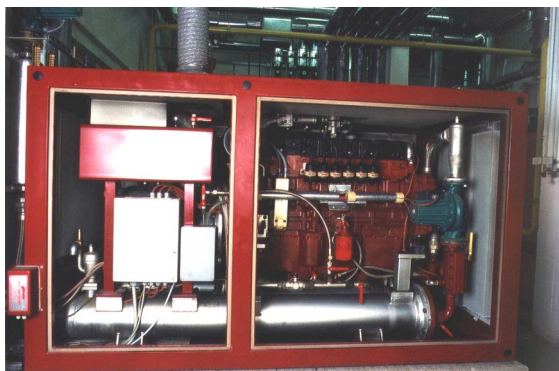


Figure 2: Small-scale CHP plant

In case of gas-fired heating, the base load must in principle be generated in a condensing boiler. For peak load, a low-temperature boiler may be used.

In principle, heating controls with a start-stop optimisation and a year-round programme should be used. For buildings that have different usage patterns in many rooms, groups of similar rooms shall be defined, or a temperature control of individual rooms shall be analysed. The opening of windows shall be automatically detected, e.g., via the sudden drop of room temperature at the room temperature sensor. Heating systems shall be designed for a temperature setting of 60 °C/ 40 °C, at maximum 70 °C/ 50 °C. Radiators have to be given preference over convectors.

At least 2 heating circuits per building should be installed. Depending on the usage conditions, further circuits are often useful (e.g., administration, gym).

Circulating pumps with more than 100 W of power input have to be equipped with a variable speed control.

Upon exchange of boilers, the boiler power must be adapted to the real heat demand of the building. The latter must be calculated either according to DIN 4701 or from the annual heating energy consumption using annual hours of use.

Thermostats either have to be limited in the maximum temperature, or blocked thermostats in public administration quality have to be used. In the base part of the thermostats, the kv value has to be fixed. Alternatively, backflow valves that can be fixed can be used.

The heating system should only enable heating at an exterior temperature (current value) of 15 °C or lower. The heating system may only be accepted after the protocol for the hydraulic optimisation has been submitted. The actual room temperatures have to be checked.

6. Ventilation and Air Conditioning

In principle, artificial ventilation should be avoided, with the exception of low energy and passive buildings. Sufficient ventilation via opening of the windows has to be enabled. If an artificial ventilation is necessary, air volume and the share of fresh air has to be minimised according to the requirements of DIN 1946.

High efficiency fans with variable speed control have to be used.

All ventilation systems have to be operated via timer programmes. If possible, controls should allow adaptation to the actual demand via step control switches or CO₂ content sensors. If possible, occupancy sensors installed for lighting control can also be used for ventilation control.

Ventilation systems shall be equipped with a heat recovery with an efficiency coefficient above 0.7, in case of more than 3,000 m³/hour and more than 1,000 hours/year above 0.75. Air-based heating systems have to be avoided (exception: passive buildings).



Figure 3: High efficiency fan

Cooling and humidification generally have to be avoided. Constructive possibilities for providing summer comfort have to be used with priority. Exceptions are possible for conservatory or medical reasons.

If rooms have to be cooled artificially, the possibilities of night and adiabatic cooling have to be used first. If district heating or CHP is used for heating, the possibility to use an absorption cooler shall be analysed. If cold has to be produced with compressors, the possibility to use ground heat exchangers has to be analysed.

Cooling may only be enabled if sun blinds are activated and at room temperatures of 27 °C and above. For museums, room temperature and humidity shall vary in the course of the year.

7. Sanitary Systems

Toilet flushes must be equipped with a stop function and a user guide. In case of a high use frequency⁴ of a WC facility, dry urinals are cost-effective. For wash basins, output must be limited to 5 litres/min, for showers to 9 litres/min. Self-shutting faucets must be used, set to shut after 5 sec for wash basins and after 20 sec for showers.

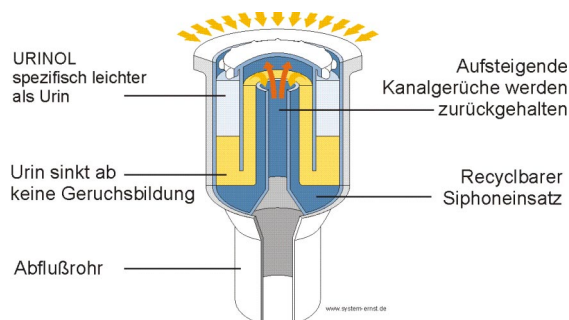


Figure 4: Dry urinal

Hot water tank volume should be chosen as small as possible, in order to prevent growth of bacteria, and heat losses. Water may be heated by a separate condensing boiler in order to minimise stand-by and distribution heat losses. Hot water tank loading must be timer controlled. For big hot water systems, measures for reducing legionellae growth must be installed⁵.

The water supply of WCs and urinals shall be separated from the general drinking water system, if an annual water demand above 100 m³ is to be expected. The use of rain or recycled water shall be assessed.

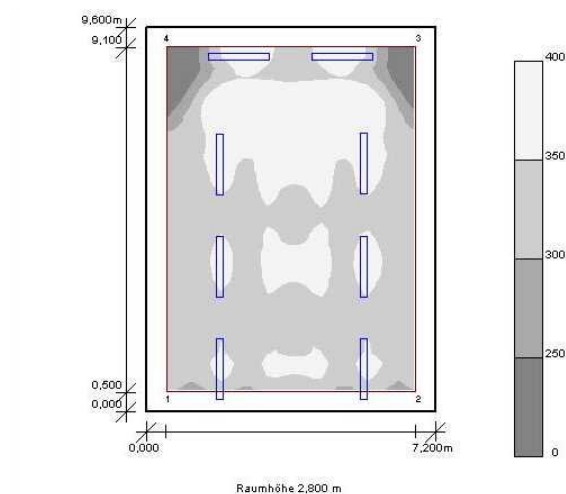
8. Lighting and Other Electric Systems

When planning artificial lighting systems, the maximum illumination levels according to DIN 5035 shall not be exceeded. A calculation with a certified simulation software is required to prove this. The actual illumination level must be measured and fixed in a protocol when taking over the lighting system from the provider.

At an illumination level of 300 lux, an installed power of 10 W/m² must not be exceeded, the target value is 7.5 W/m². At an illumination level of 500 lux, the maximum value is 15 W/m², the target value is 11 W/m².

⁴ cf. AMEV Sanitärbaubau 95

⁵ nach DVGW Arbeitsblatt 551 und 552



Em in lx(°)	Emax in lx(°)	Emin in lx(°)	Emin/Em(°)	Emin/Emax(°)
339	462	128	1:2,8	1:3,5

*)... Nutzebene vermindert um 0,500 m Randzone

Figure 5: Lighting simulation for a classroom

These levels can be achieved, if lamps with a lighting efficiency of at least 50 lm/W and luminaires with a lighting efficiency of at least 80 % are used. Generally, electronic ballasts must be used.

In larger rooms, lighting shall be made separately switchable for the window and wall sides, or be controlled by a daylight and occupancy sensor. Switches have to be marked.

For groups of luminaires above 1 kW of installed power, lighting shall be controlled by daylight and occupancy sensors. For hallways, the use of occupancy sensors combined with light sensors or time relays is recommended.

Lighting for bathrooms, toilets, or dressing rooms has to be occupancy-controlled.

Exterior lighting must be controlled via light sensors, timer, and maybe in combination with a movement sensor.

IT and office equipment shall comply with the values of the GEEA label ⁶.

New household appliances must generally have an energy label Class A.

Electric motors must have a high efficiency (From 750 h/year class eff2, from 1500 h/year class eff1⁷)

Kitchens shall be operated with gas as far as possible. Power factor correction equipment shall be installed if the power factor is lower than the values allowed by the electricity supplier.

If possible, small-scale CHP plants shall be chosen to provide uninterrupted power supply, if they can be operated with natural gas, and the waste heat can be used.

9. Monitoring and Control Systems

Generally, all systems have to be designed such that they can be connected to a common control centre. Digital controls shall be used, with a manufacturer-independent connection to the network. For all separate buildings, individual meters have to be installed with a separate output channel for electricity, heat, and water, if necessary as sub-meters.

User-friendliness is the highest priority when installing building control technology. E.g., maps and documentation for retrieval of equipment must exist, actual and standard values must be included in the plant schemes. It must be easy for the user to create and change timer programmes. The use of systems for restriction of maximum power has to be assessed.

⁶ www.Energielabel.de

⁷ www.eff1-sparmotor.de

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