



INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

IEA SOLAR HEATING AND COOLING PROGRAMME

TASK 27

PERFORMANCE OF SOLAR FACADE COMPONENTS

PROJECT A2

**Simulation results for reference office
with electrochromic and gasochromic glazings**

October 2002

Toke Rammer Nielsen
Technical University of Denmark
Department of Civil Engineering

1 Input

The influence gasocromic and electrochromic glazings in the bleached and coloured state on the heating and cooling demand are evaluated for the reference office described by Dick van Dijk (IEA27-r-a-2-TNO-Sept.2001-Ref.office_v-1.0.pdf and IEA27-r-a-2add-TNO-April 2002-Ref.office_v-1.0-addendum.doc) with climate for Rome, Brussels and Stockholm as supplied by Werner Platzer (swift-wp3-ise-wjp-meteodata.xls).

The U-value and angle dependent g-value of the different glazing types are used in the model. For both glazings the data for air mass 1.5 is used. The gasocromic data is described in swift-wp1-ip-020308_gasocromic_design_data.doc and the electrochromic data is described in r-a2-sg-xf-020918-Saint-Gobain-Electrochromic-design-data.doc. The values used in the simulations are summarized in Table 1.

Table 1. Glazing properties.

	U_{center} [W/m ² K]	Ψ_{edge} [W/mK]	g [-]
Reference	1.30	0.06	0.531
Gasocromic bleached AM 1.5	0.93	0.06	0.463
Gasocromic coloured AM 1.5	0.93	0.06	0.130
Electrochromic bleached	1.16	0.06	0.288
Electrochromic coloured	1.16	0.06	0.105

The set points for cooling differ from the reference case as described in the addendum. In the simulations the set points from the first version of the reference office are used. For cooling the set points used in the calculations are:

Monday-Friday:	00.00-06.00 hr	28°C
	06.00-18.00 hr	24°C
	18.00-24.00 hr	28°C
Weekend:	00.00-24.00 hr	28°C

2 Results

The monthly results for heating and cooling demand and maximum inside surface temperature on the glazing are given in tables for electrochromic and gasocromic glazings in the coloured and bleached state for each location. The yearly heating, cooling and lighting energy demands are illustrated in a figure and compared to the reference case.

The calculations have been performed using the Danish simulation program Bsim. The Bsim model handles windows in a simplified way. It assumes steady state conditions for heat flow and the heat loss in a given time step for the window is $U \cdot A \cdot \Delta T$. The temperatures calculated on the window surfaces are based on the heat balance of the surface based only on the transmitted heat and are not influenced by any solar radiation absorbed in the panes. Therefore, the calculated surface temperatures are too low in cases with a high level of incident solar radiation. The solar energy transmitted to the room is $g(i) \cdot I_{dir} + g_{dif} \cdot (I_{ref} + I_{dif})$, where $g(i)$ and g_{dif} are the total solar energy transmittance for direct radiation depending on the incidence angle and the total solar energy transmittance for diffuse radiation, and I_{dir} , I_{dif} and I_{ref} are the direct, diffuse and reflected components of solar radiation incident on the outside of the surface.

The yearly energy consumption for lighting is defined in the description of the reference office. There is no lighting control in the simulations and the energy used for lighting is therefore the same in all cases. The yearly electric energy for lighting is 349 kWh pr. office module and 88 kWh in the corridor. This gives a total yearly energy consumption for lighting at 786 kWh. All heat generated by the lighting in the corridor is

supplied to the air. In the office rooms 67% of the lighting energy is supplied to the air giving a yearly heat supply of 234 kWh pr. office module.

2.1 Rome

Table 2. Electrochromic coloured Rome

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan	0	87	0	104	20	19
Feb	0	62	0	73	23	22
Mar	0	44	0	51	22	21
Apr	0	19	0	21	25	25
Maj	-25	0	-22	0	25	25
Jun	-70	0	-67	0	26	26
Jul	-119	0	-114	0	27	27
Aug	-117	0	-108	0	27	27
Sep	-61	0	-48	0	26	25
Okt	-16	0	-5	0	24	24
Nov	0	14	0	17	23	23
Dec	0	66	0	78	20	20
Tot	-408	293	-364	345		

Table 3. Electrochromic bleached Rome

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan	0	64	0	84	22	20
Feb	-2	37	0	53	24	23
Mar	0	25	0	33	23	22
Apr	-10	7	-3	9	25	25
Maj	-58	0	-44	0	25	25
Jun	-98	0	-89	0	27	27
Jul	-150	0	-138	0	28	28
Aug	-152	0	-129	0	28	28
Sep	-103	0	-66	0	27	26
Okt	-71	0	-15	0	25	24
Nov	-10	3	0	7	23	23
Dec	0	41	0	56	22	20
Tot	-653	177	-485	242		

Table 4. Gasocromic coloured Rome

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan	0	77	0	94	20	20
Feb	0	52	0	65	23	23
Mar	0	37	0	44	22	22
Apr	-1	14	0	16	25	25
Maj	-32	0	-27	0	25	25
Jun	-75	0	-71	0	26	26
Jul	-123	0	-117	0	27	27
Aug	-121	0	-111	0	27	27
Sep	-68	0	-52	0	26	25
Okt	-26	0	-8	0	24	24
Nov	0	10	0	13	23	23
Dec	0	56	0	68	20	20
Tot	-446	246	-386	299		

Table 5. Gasocromic bleached Rome

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan	-10	44	0	62	23	21
Feb	-15	18	0	29	26	24
Mar	-17	11	0	17	24	23
Apr	-41	1	-12	2	25	25
Maj	-95	0	-71	0	26	25
Jun	-127	0	-113	0	27	27
Jul	-180	0	-161	0	29	28
Aug	-187	0	-150	0	29	28
Sep	-146	0	-86	0	28	27
Okt	-133	0	-31	0	27	25
Nov	-46	0	-1	1	26	23
Dec	-8	21	0	33	25	21
Tot	-1004	95	-625	143		

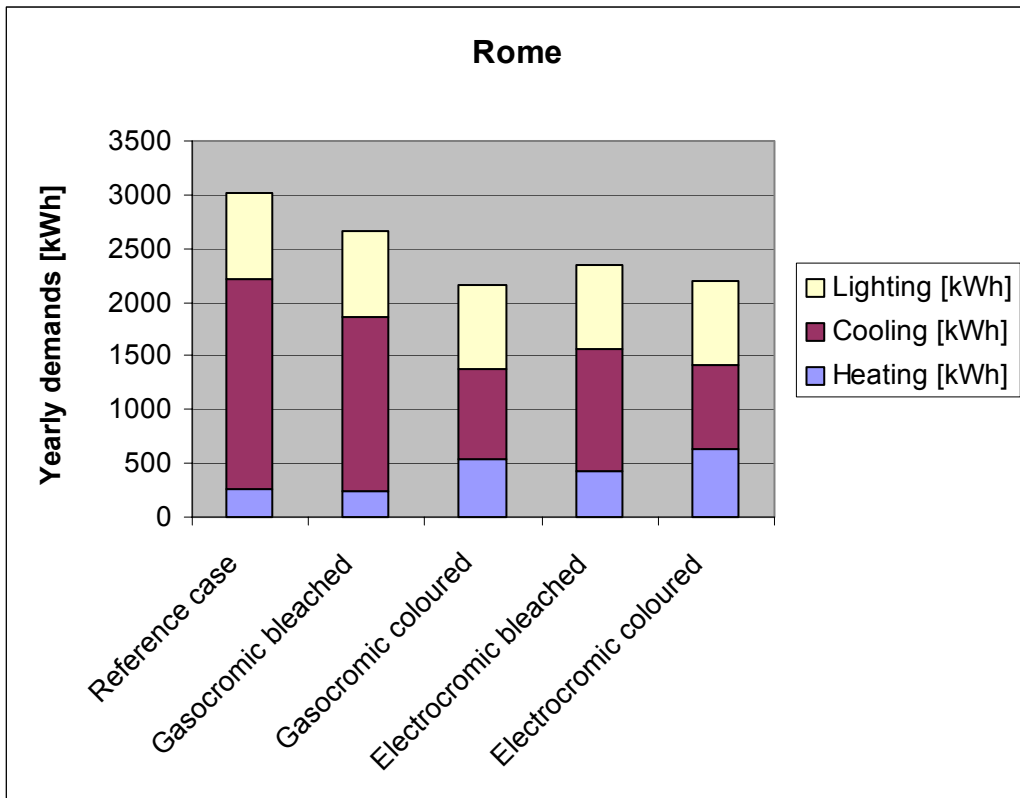


Figure 1. Yearly heating, cooling and lighting demands for Rome.

2.2 Brussels

Table 6. Electrochromic coloured Brussels

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan	0	160	0	167	19	19
Feb	0	120	0	130	19	19
Mar	0	104	0	114	20	20
Apr	0	48	0	52	22	22
Maj	-1	11	0	11	24	24
Jun	-16	5	-14	5	25	25
Jul	-36	0	-31	0	25	25
Aug	-42	1	-37	1	27	27
Sep	-4	0	-1	0	24	24
Okt	0	33	0	37	22	22
Nov	0	99	0	106	19	18
Dec	0	144	0	152	18	18
Tot	-99	725	-83	776		

Table 7. Electrochromic bleached Brussels

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan	0	145	0	160	20	19
Feb	0	99	0	120	20	19
Mar	0	83	0	97	21	21
Apr	0	29	0	34	23	23
Maj	-13	3	-5	3	24	24
Jun	-36	1	-27	1	25	25
Jul	-68	0	-53	0	26	26
Aug	-69	0	-51	0	28	27
Sep	-30	0	-8	0	24	24
Okt	0	18	0	23	23	23
Nov	0	84	0	94	20	18
Dec	0	128	0	147	18	18
Tot	-216	589	-144	678		

Table 8. Gasocromic coloured Brussels

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan		0	148	0	157	19
Feb		0	109	0	120	19
Mar		0	94	0	105	20
Apr		0	40	0	44	22
Maj		-2	7	-1	8	24
Jun		-19	3	-16	3	25
Jul		-42	0	-36	0	25
Aug		-46	0	-40	0	27
Sep		-8	0	-2	0	24
Okt		0	27	0	30	22
Nov		0	89	0	97	19
Dec		0	133	0	143	18
Tot		-118	651	-95	707	

Table 9. Gasocromic bleached Brussels

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan		0	122	0	143	22
Feb		0	75	0	99	22
Mar		-1	60	0	74	23
Apr		-1	13	0	15	24
Maj		-42	1	-18	1	26
Jun		-65	0	-48	0	27
Jul		-104	0	-79	0	27
Aug		-103	0	-70	0	29
Sep		-67	0	-20	0	25
Okt		-11	6	0	9	24
Nov		0	64	0	75	21
Dec		0	107	0	130	20
Tot		-393	448	-235	547	

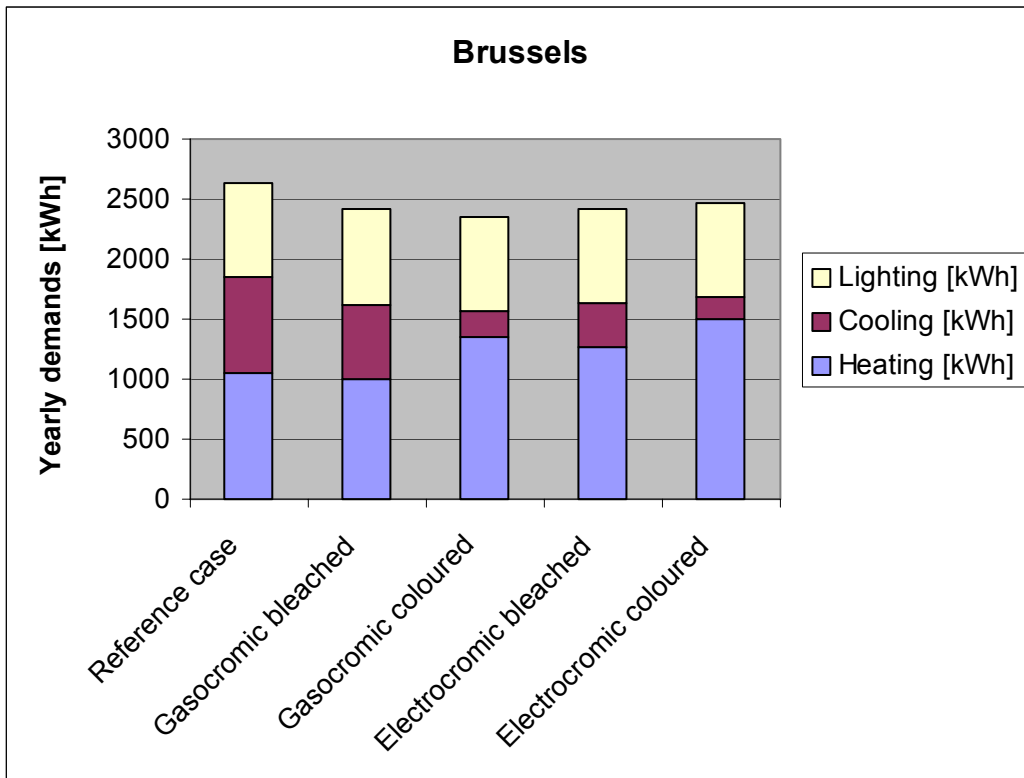


Figure 2. Yearly heating, cooling and lighting demands for Brussels.

2.3 Stockholm

Table 10. Electrochromic coloured Stockholm

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan	0	259	0	268	17	17
Feb	0	216	0	232	18	18
Mar	0	190	0	212	18	18
Apr	0	104	0	119	20	19
Maj	0	38	0	42	22	22
Jun	-16	5	-10	5	24	24
Jul	-39	0	-31	0	25	25
Aug	-30	0	-22	0	25	25
Sep	0	11	0	13	21	21
Okt	0	79	0	94	19	19
Nov	0	158	0	167	18	18
Dec	0	200	0	206	17	17
Tot	-84	1259	-63	1358		

Table 11. Electrochromic bleached Stockholm

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]
Jan	0	243	0	264	17	17
Feb	0	186	0	224	19	18
Mar	0	146	0	195	19	18
Apr	0	72	0	95	21	20
Maj	-1	17	0	22	24	23
Jun	-50	1	-29	1	24	24
Jul	-81	0	-55	0	26	26
Aug	-73	0	-39	0	25	25
Sep	-1	1	0	3	23	22
Okt	0	55	0	75	21	19
Nov	0	139	0	161	18	18
Dec	0	187	0	202	17	17
Tot	-207	1047	-122	1241		

Table 12. Gasocromic coloured Stockholm

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]	
Jan		0	244	0	254	17	17
Feb		0	200	0	219	18	18
Mar		0	172	0	199	18	18
Apr		0	91	0	108	20	19
Maj		0	30	0	35	23	22
Jun		-22	3	-14	3	24	24
Jul		-47	0	-36	0	25	25
Aug		-38	0	-26	0	25	25
Sep		0	7	0	9	22	22
Okt		0	68	0	84	20	19
Nov		0	146	0	157	18	18
Dec		0	187	0	195	18	18
Tot		-106	1149	-76	1261		

Table 13. Gasocromic bleached Stockholm

	Cooling south office [kWh]	Heating south office [kWh]	Cooling north office [kWh]	Heating north office [kWh]	Max. temp South window [°C]	Max. temp North window [°C]	
Jan		0	215	0	246	19	17
Feb		0	152	0	200	20	18
Mar		0	103	0	162	21	18
Apr		0	43	0	61	22	21
Maj		-28	6	-1	9	24	23
Jun		-97	0	-55	0	26	25
Jul		-127	0	-83	0	28	26
Aug		-123	0	-62	0	26	26
Sep		-28	0	0	0	25	23
Okt		-2	35	0	50	22	20
Nov		0	115	0	143	20	18
Dec		0	164	0	187	18	18
Tot		-405	833	-200	1056		

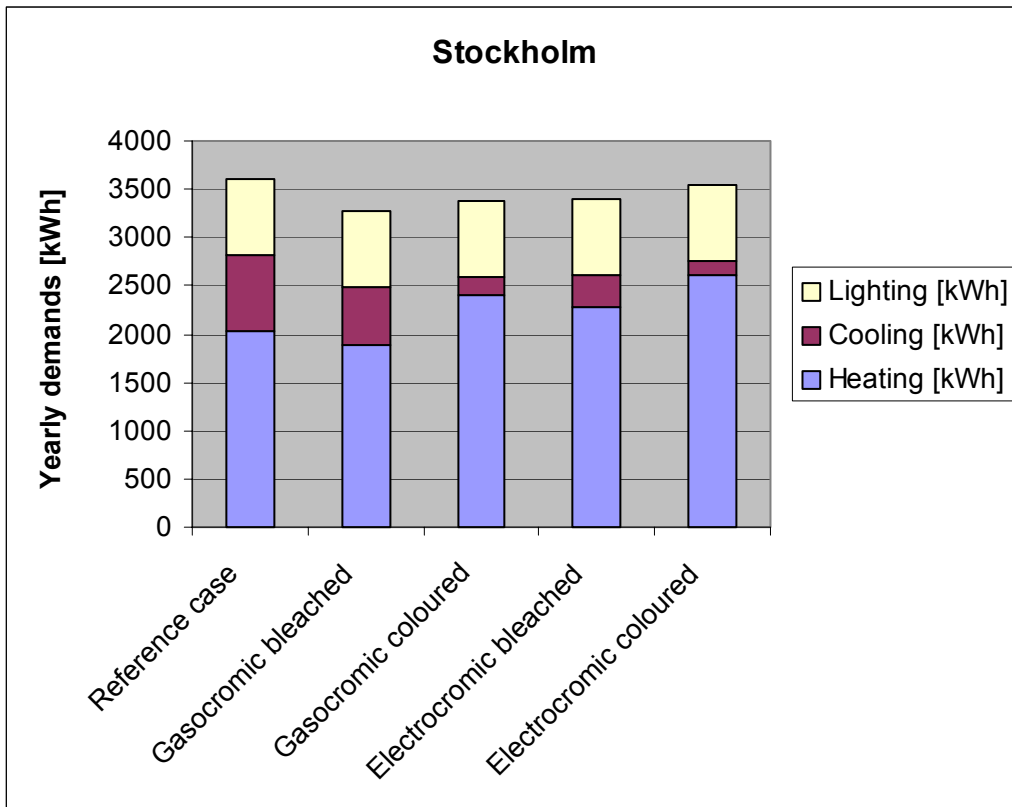


Figure 3. Yearly heating, cooling and lighting demands for Stockholm.

3 Seasonal heating and cooling demands

Using the calculated monthly heating and cooling demands in the bleached and colored states, it is possible to estimate the yearly heating and cooling demands in a situation where the glazings are colored during the cooling season and bleached during the heating season. The months in which the windows are colored are indicated by the cooling periods in Table 14. In the remaining months, the windows are in the bleached state. At each location and for each office separately, for each month, the window state (bleached or coloured) was chosen, which had the lower total energy consumption. The seasonal heating and cooling demands for the electrochromic and gasochromic glazings in the north and south facing office rooms are shown in Table 14 for Rome, Brussels and Stockholm.

Table 14. Heating and cooling demands using seasonal switching.

Location	Window	Cooling period south	Cooling south [kWh]	Heating south [kWh]	Cooling period north	Cooling north [kWh]	Heating north [kWh]
Rome	electrochromic	May-Oct	-430	177	May-Oct	-367	242
Rome	gasochromic	Apr-Nov	-496	118	May-Oct	-399	143
Brussels	electrochromic	May-Sep	-99	602	Jun-Sep	-88	683
Brussels	gasochromic	May-Sep	-131	457	May-Sep	-95	557
Stockholm	electrochromic	Jun-Aug	-86	1051	Jun-Aug	-63	1245
Stockholm	gasochromic	May-Sep	-108	867	Jun-Aug	-77	1059