TARTU ÜLIKOOL

Päikese vabasoojuse kasutus - akende energiabilanss

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Lühidalt tuleb juttu

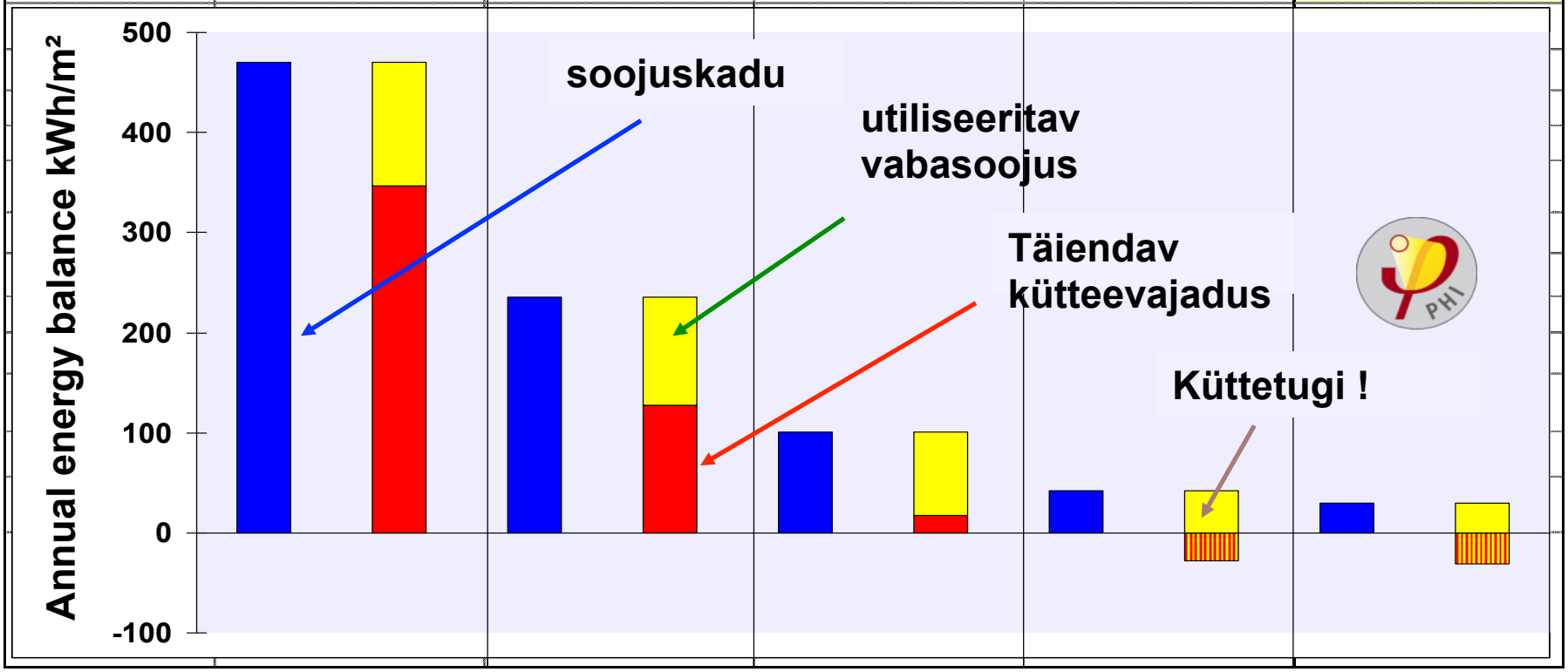
Akende energiabilansist,

- Eestis talvel akna soojusbilanss positiivne, kas võimalik?
- Mis tingimustel (suund, kvaliteet, fragmentatsioon)?
- Milline on dünaamika 43 aasta vältel?

(Komponentide valikust ja mõjust).

Klaaspakettide areng

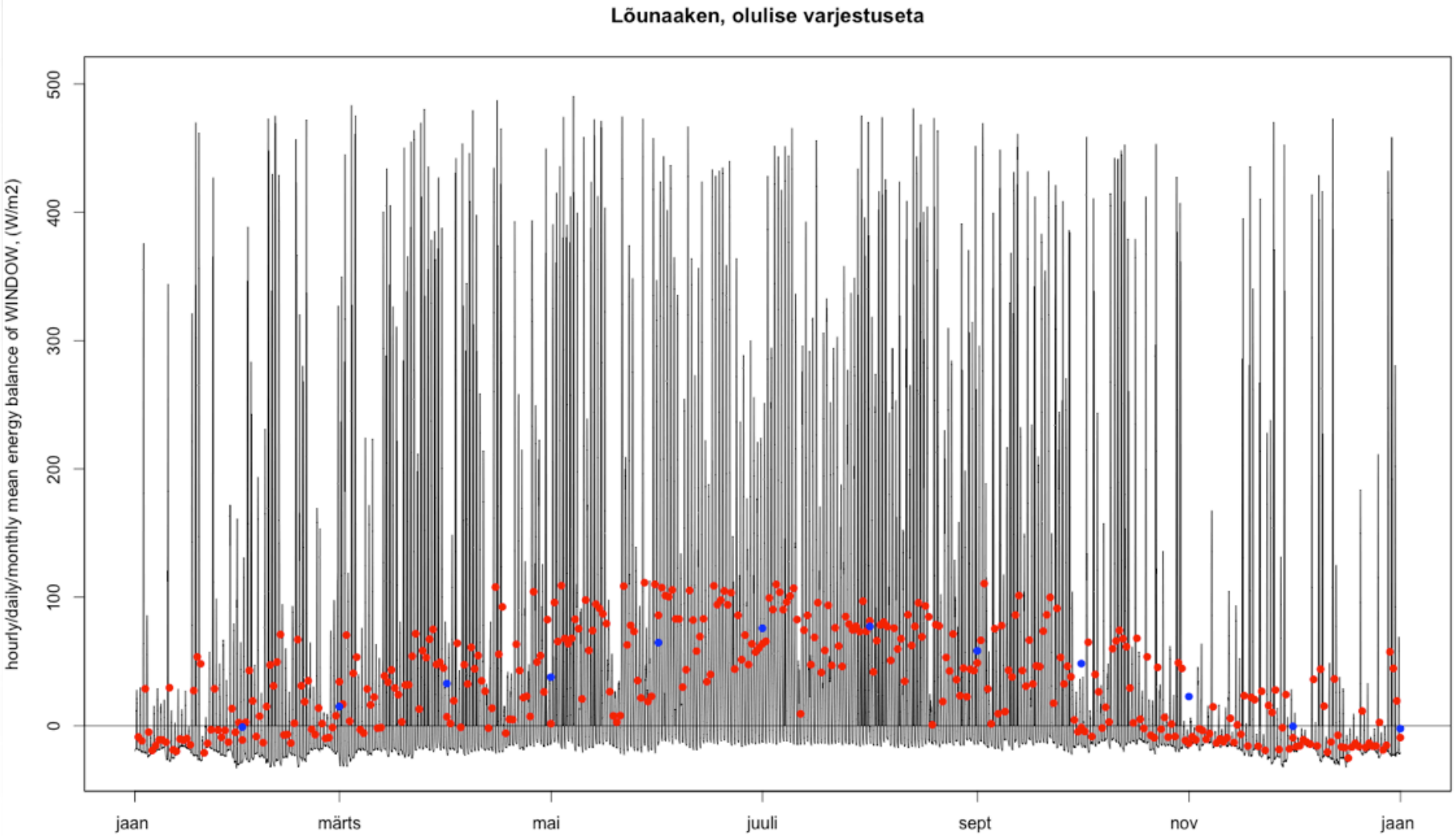
glazing	1x klaas	2x klaas	low-e klaaspakett (2x klaas)	low-e klaaspaket t (3x klaas)	Future: vacuum/ multi-foil
U_g-value (W/(m²K))	5,60	2,80	1,20	0,50	0,35
surf. temp	-1,8 °C	9,1 °C	15,3 °C	18,1 °C	18,6 °C
g-value	0,92	0,80	0,62	0,52	0,45



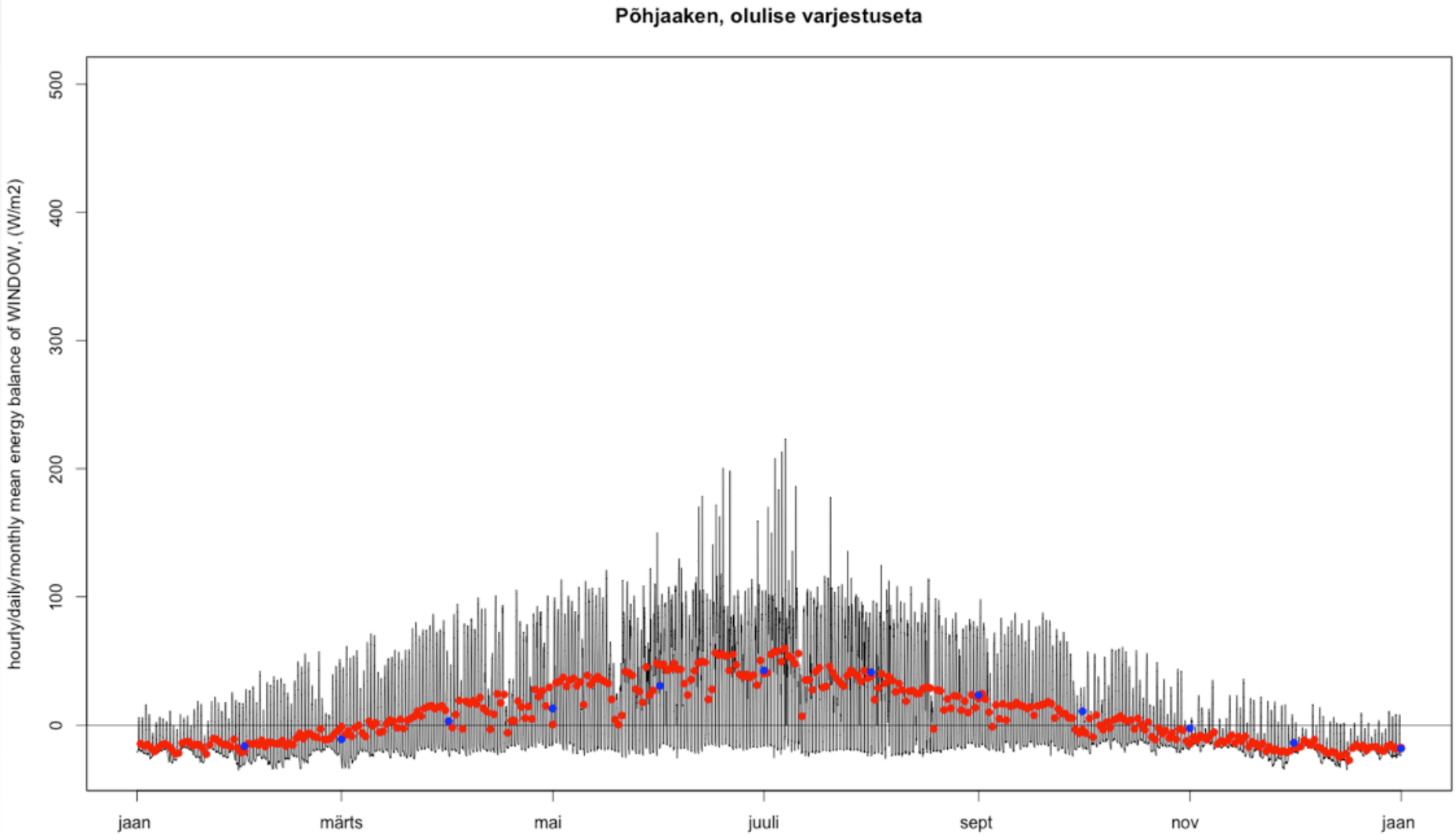
Akna energiabilanss

- Tumma välispiirdega võrreldes domineerivad erinevad protsessid;
- Ajaline variatsioon suur;
- Palju olulisi mõjutegureid:
  - komponendid;
  - varjutusolud ja orientatsioon/kaldenurk;
  - nö. fragmentatsioon;
  - kliimatingimused (ajas).

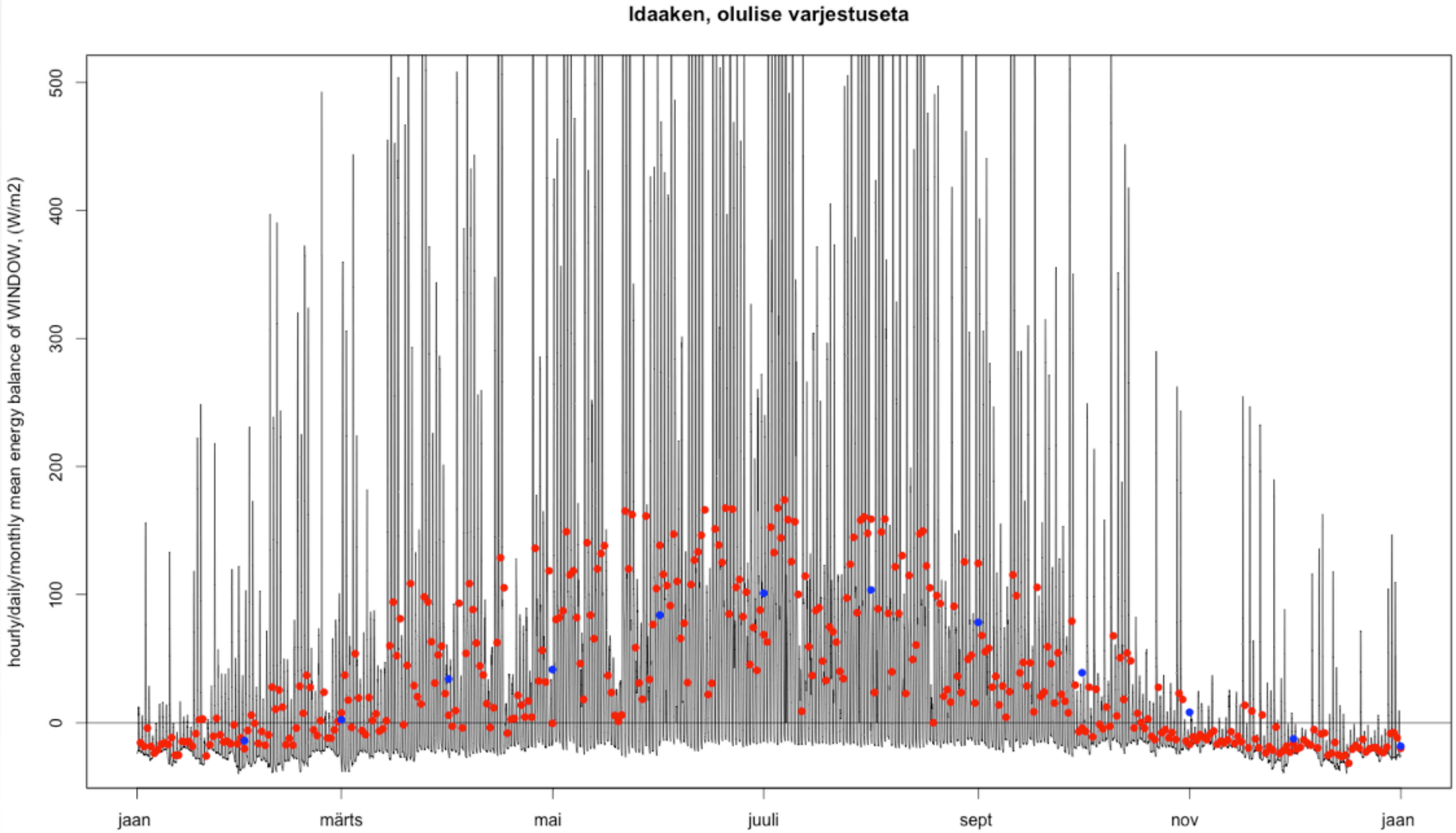
BILANSI AJALINE VARIATSIOON



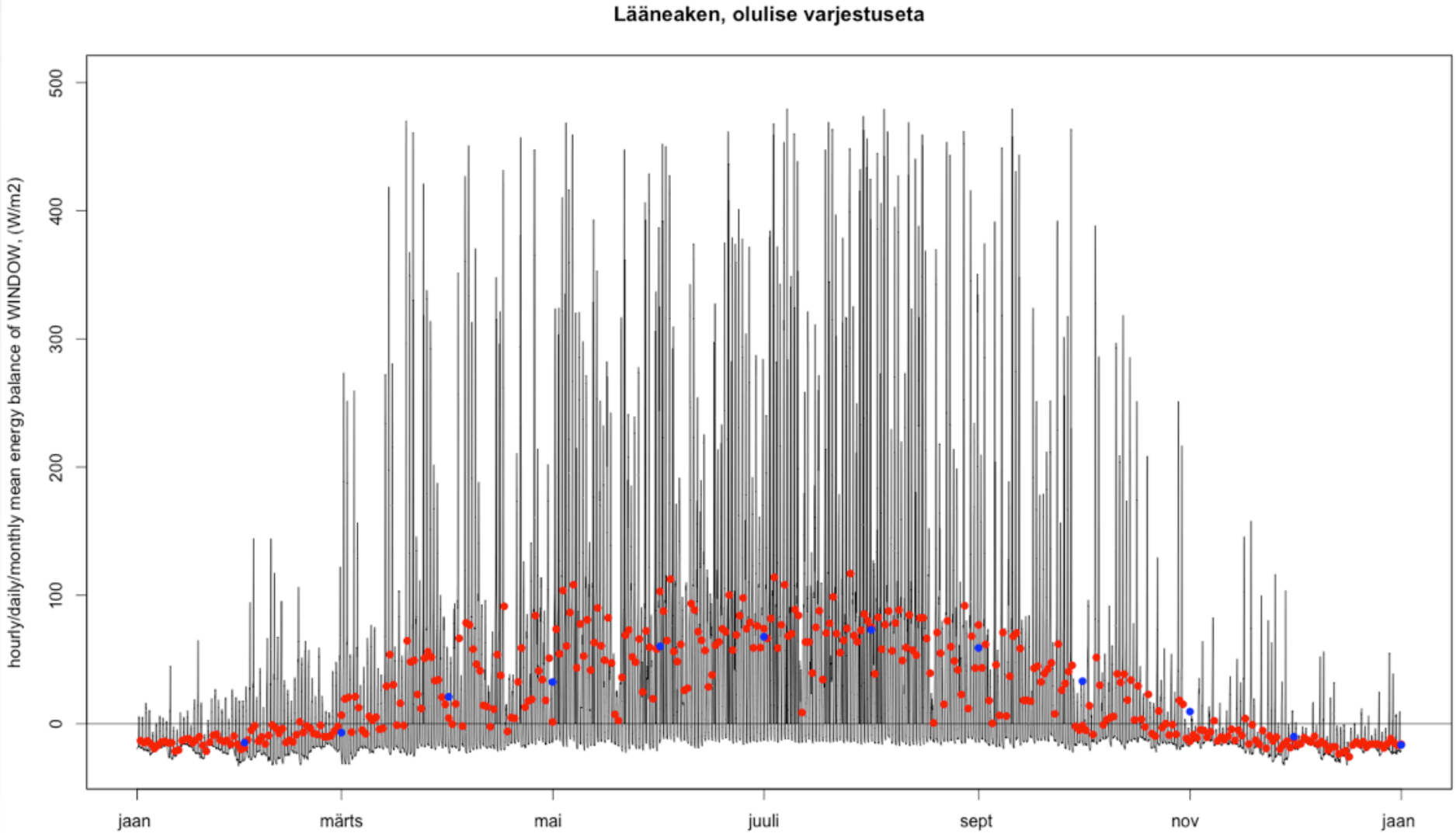
(Guardian CGN + 18Ar + kirgas klaas + 18Ar + Guardian CG Premium) + RAAM:PRO-Passivhausfenster SmartWin + KS(0,036 + 0,030 W/mK)



(Guardian CGN + 18Ar + kirgas klaas + 18Ar + Guardian CG Premium) + RAAM:PRO-Passivhausfenster SmartWin + KS(0,036 + 0,030 W/mK)

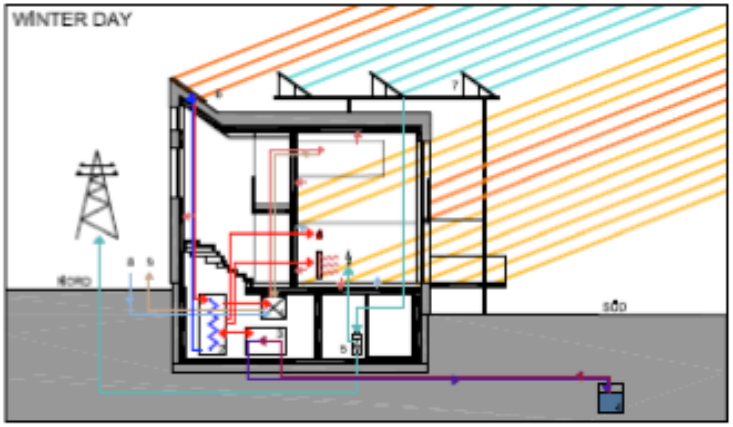


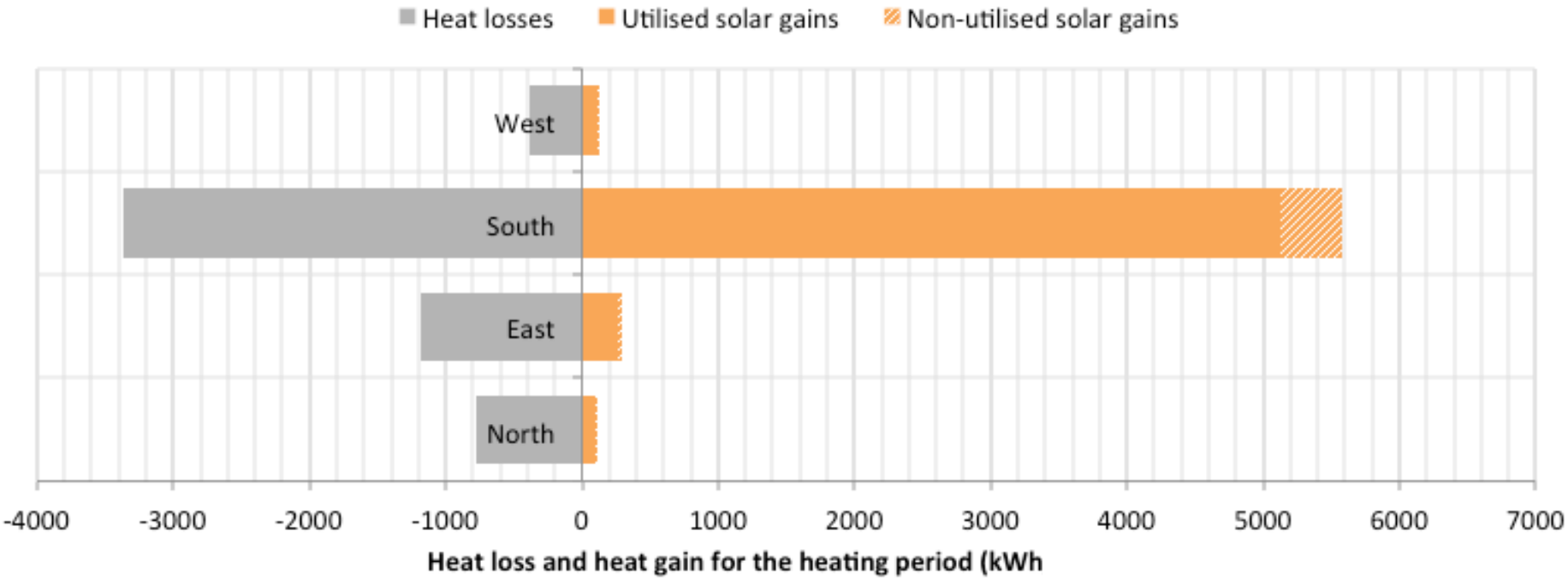
(Guardian CGN + 18Ar + kirgas klaas + 18Ar + Guardian CG Premium) + RAAM:PRO-Passivhausfenster SmartWin + KS(0,036 + 0,030 W/mK)



(Guardian CGN + 18Ar + kirgas klaas + 18Ar + Guardian CG Premium) + RAAM:PRO-Passivhausfenster SmartWin + KS(0,036 + 0,030 W/mK)

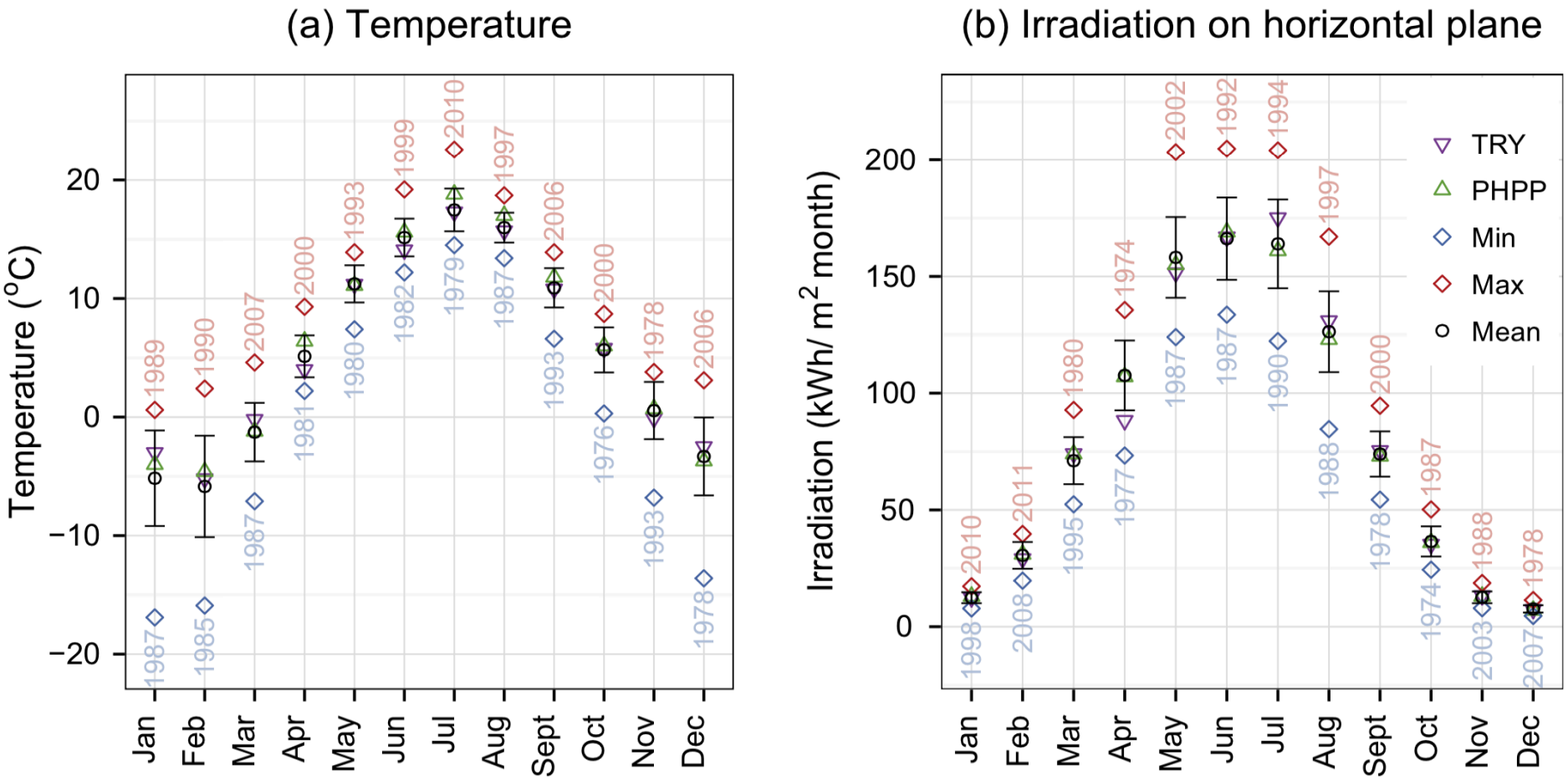
Metsa 5a eramu, Põlva





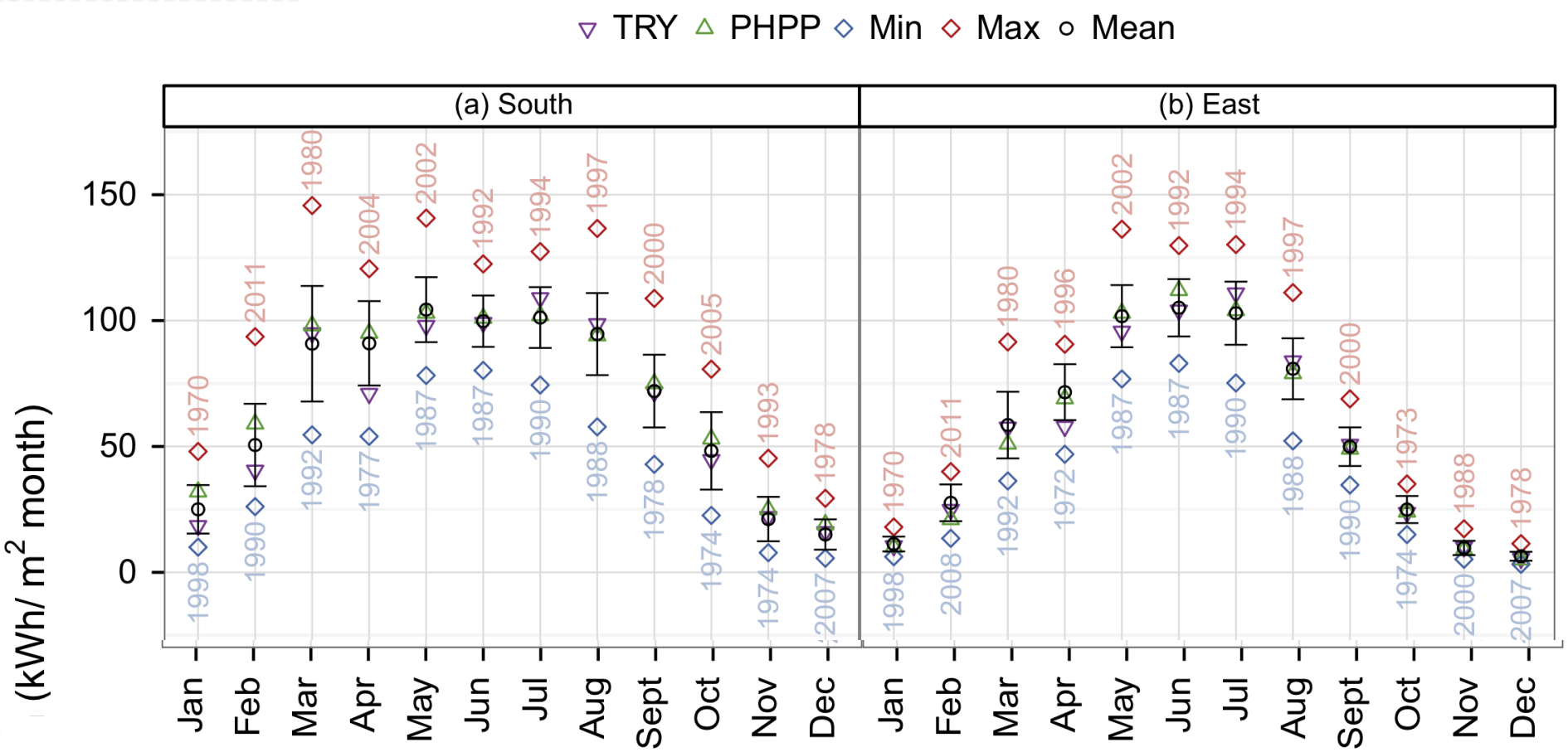
AKNA BILANSI VARIATSIOON AASTATE LÕIKES

Välisõhu temperatuur ja kiirguskliima aastatel 1970-2012 (Tõravere seireandmed)



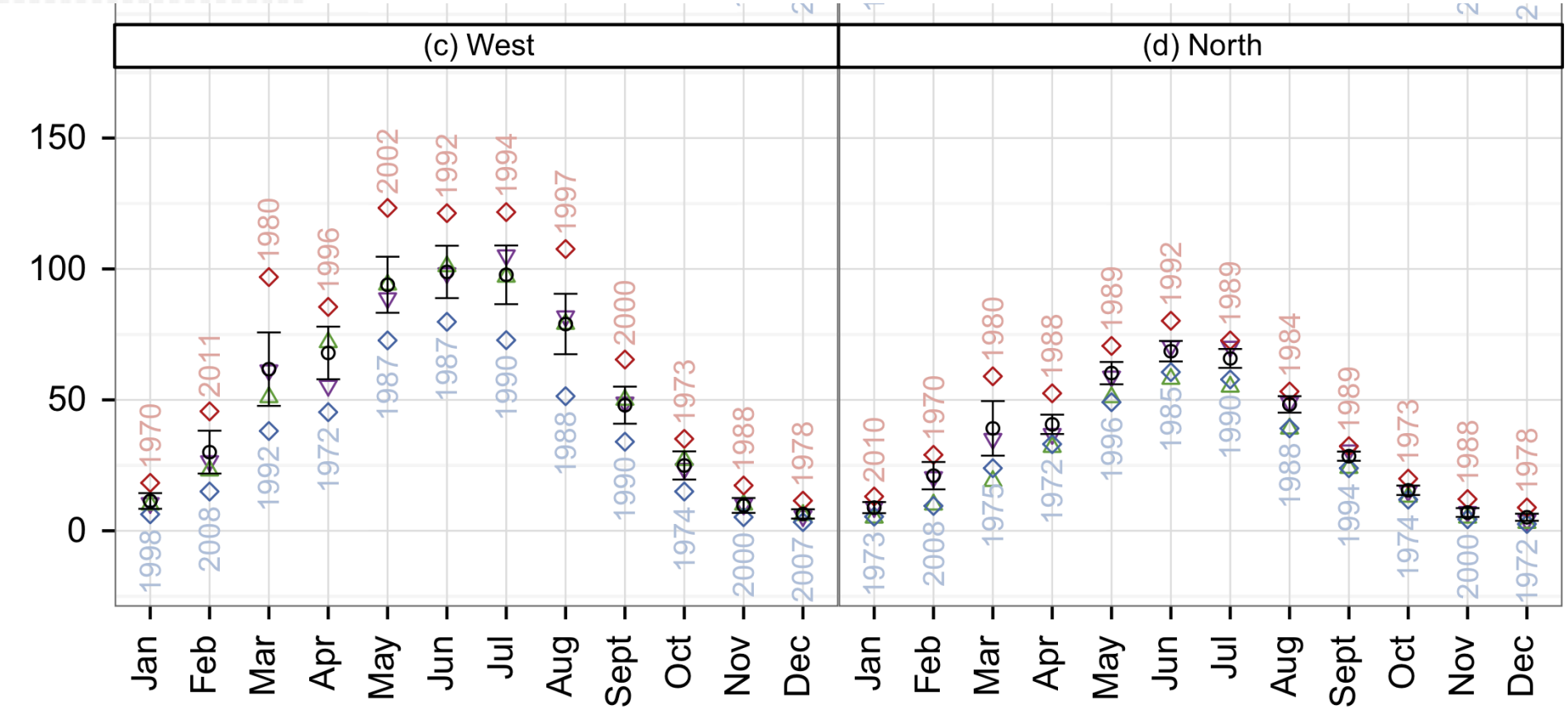
Välisõhu temperatuur ja kiirguskliima aastatel 1970-2012 (Tõravere seireandmed)

LÕUNA ja IDAFASSAAD

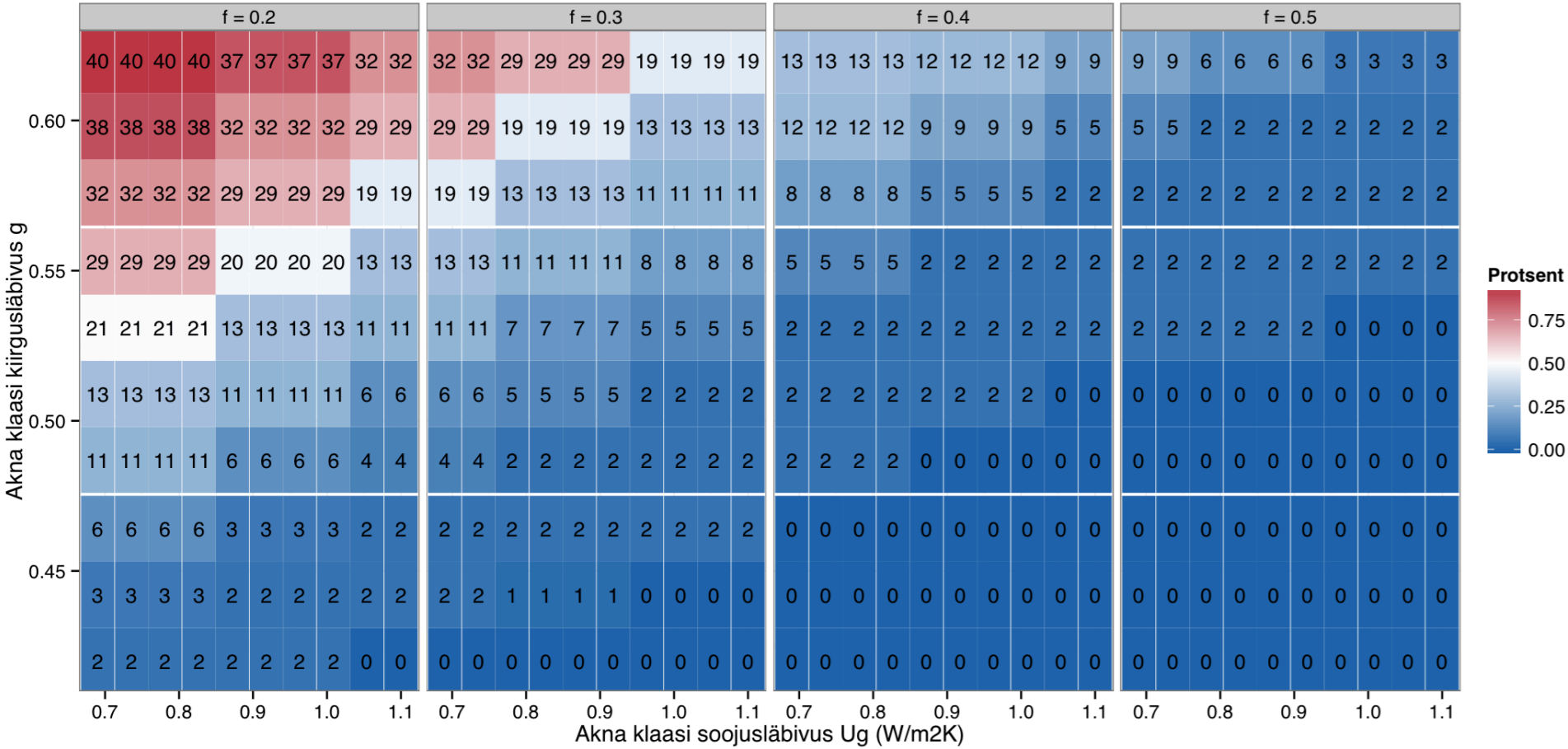


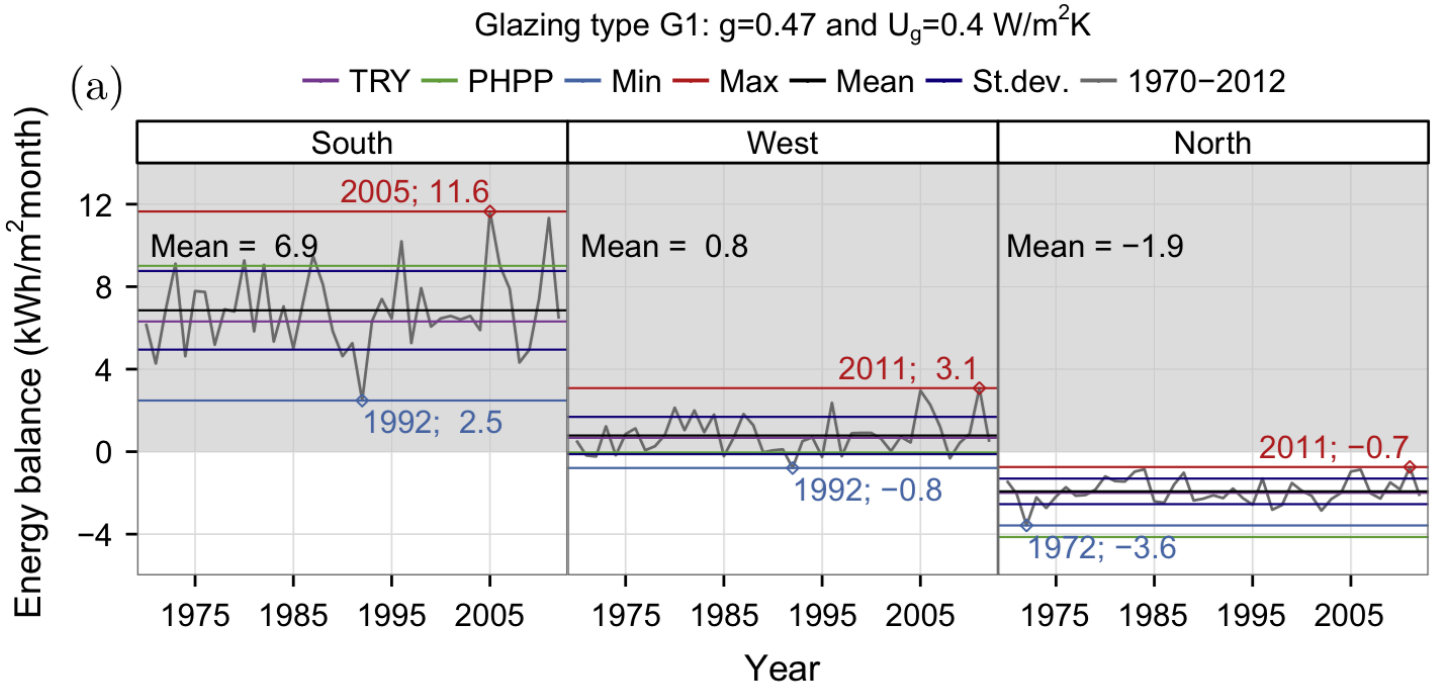
Välisõhu temperatuur ja kiirguskliima aastatel 1970-2012 (Tõravere seireandmed)

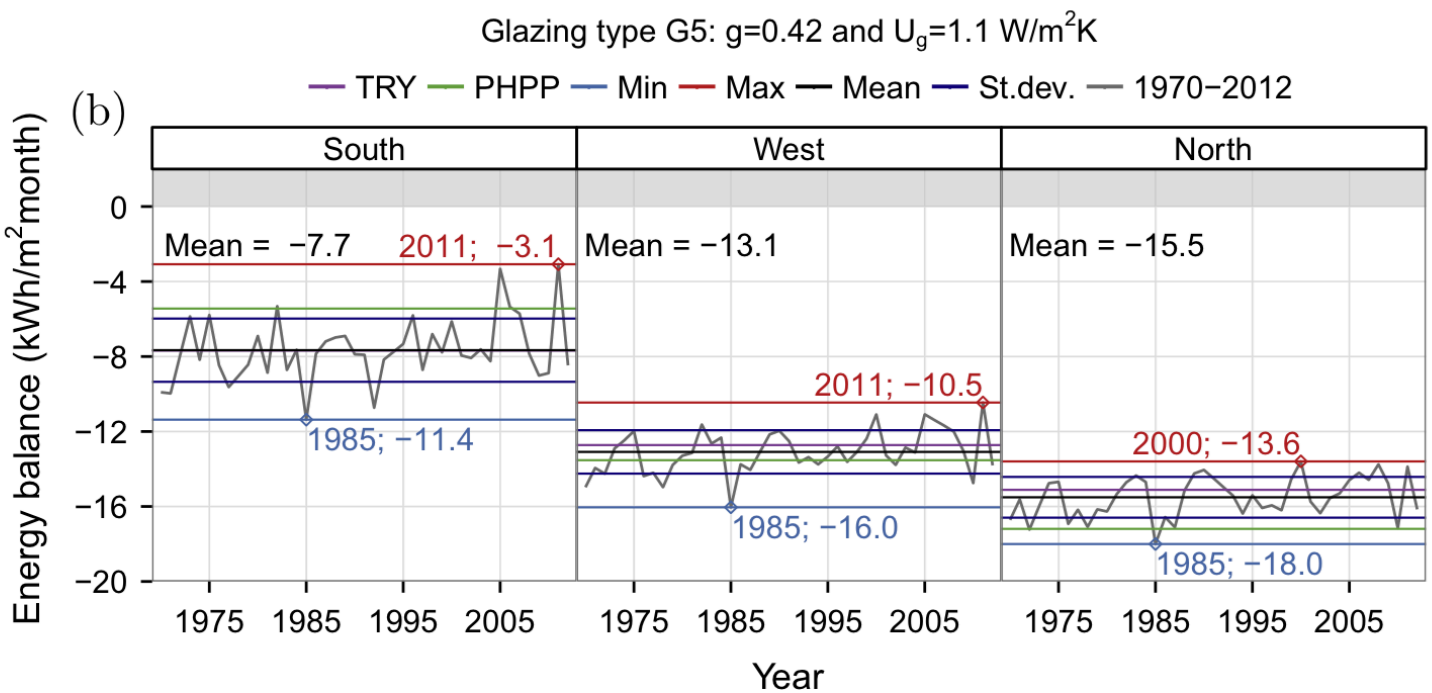
LÄÄNE ja PÕHJAFASSAAD

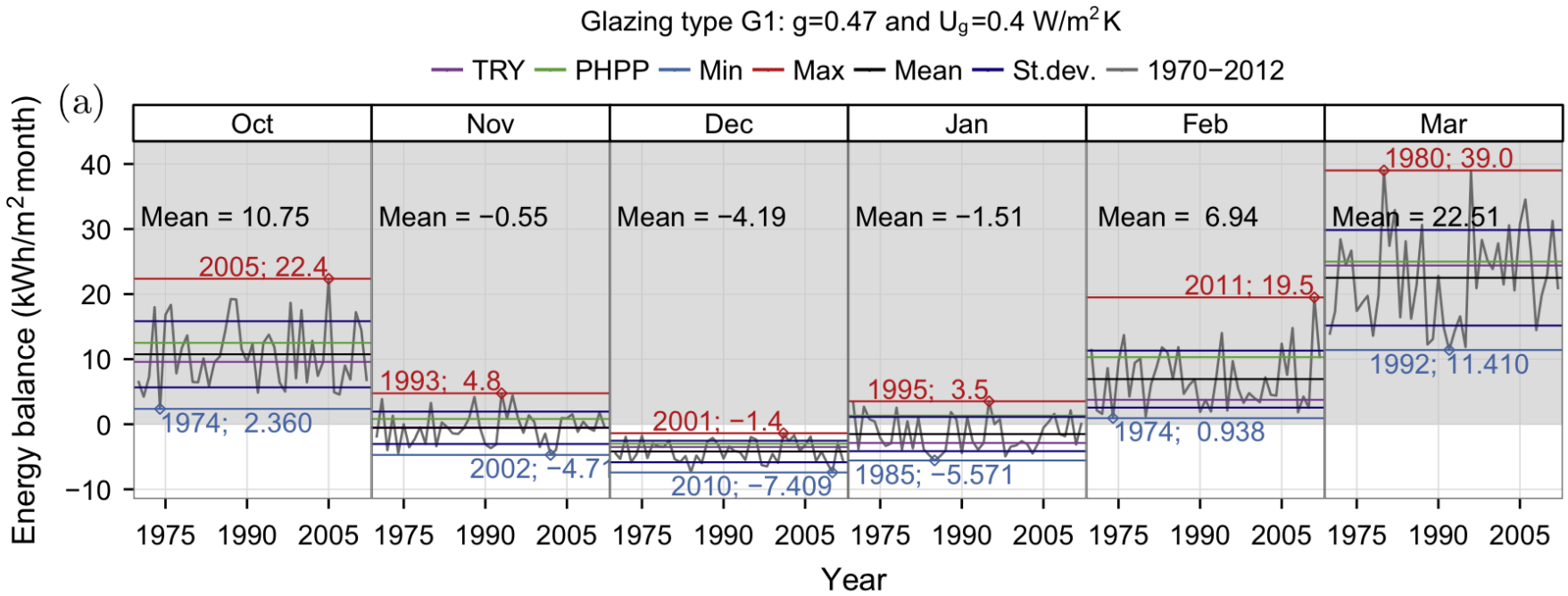


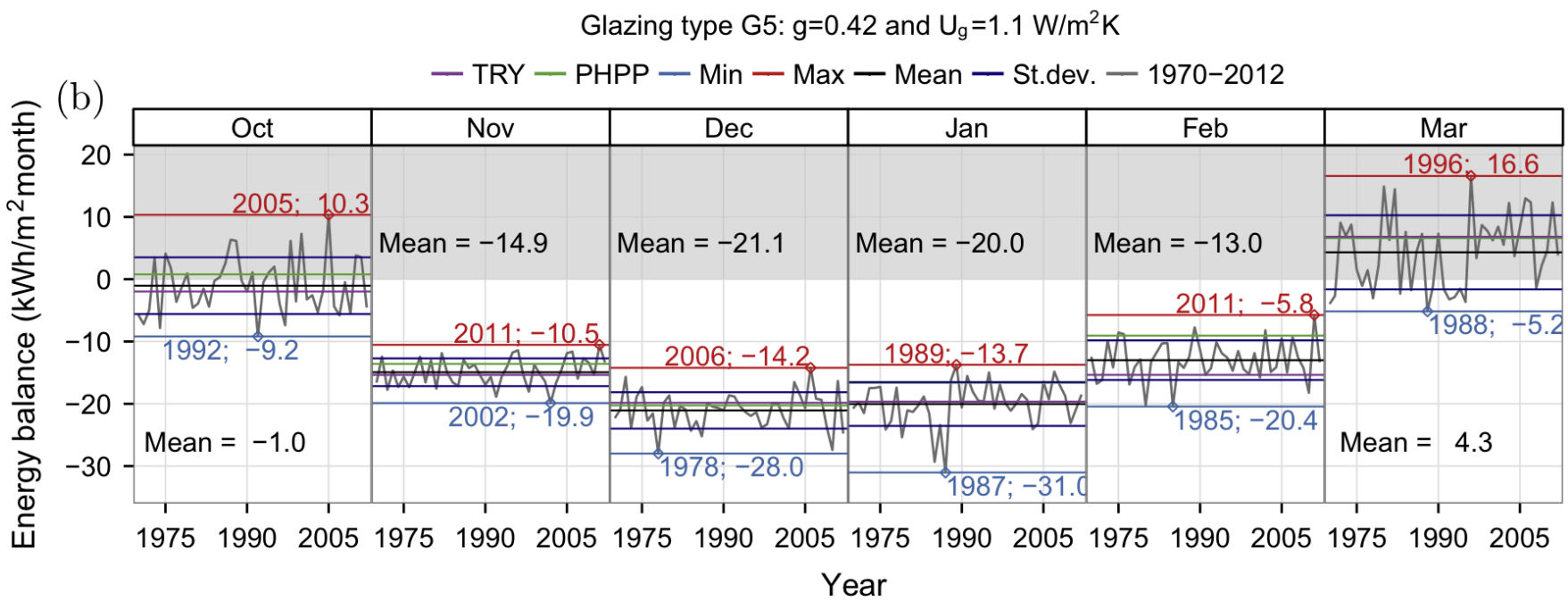
f - raami osakaal, maatriksis numbriliselt aastate hulk, mille korral akende bilanss on arvutuslikult positiivne (kütteperioodil).




Glazing type G1: g=0.47 and U_g=0.4 W/m^{2}K
(a)
TRY
PHPP
Min
Max
Mean
St.dev.
1970−2012
South
West
North
Energy balance (kWh/m^{2}month)
Mean = 6.9
2005; 11.6
1992; 2.5
Mean = 0.8
2011; 3.1
1992; −0.8
Mean = −1.9
2011; −0.7
1972; −3.6
Year


Glazing type G5: g=0.42 and U_g=1.1 W/m^{2}K
(b)
TRY
PHPP
Min
Max
Mean
St.dev.
1970−2012
South
West
North
Energy balance (kWh/m^{2}month)
Mean = −7.7
2011; −3.1
1985; −11.4
Mean = −13.1
2011; −10.5
1985; −16.0
Mean = −15.5
2000; −13.6
1985; −18.0
Year


Glazing type G1: g=0.47 and Ug=0.4 W/m2K
TRY
PHPP
Min
Max
Mean
St.dev.
1970−2012
(a)
Oct
Nov
Dec
Jan
Feb
Mar
Mean = 10.75
Mean = −0.55
Mean = −4.19
Mean = −1.51
Mean = 6.94
Mean = 22.51
2005; 22.4
1974; 2.360
1993; 4.8
2002; −4.71
2001; −1.4
2010; −7.409
1995; 3.5
1985; −5.571
2011; 19.5
1974; 0.938
1980; 39.0
1992; 11.410
Energy balance (kWh/m2month)
Year


Glazing type G5: g=0.42 and Ug=1.1 W/m2K
TRY
PHPP
Min
Max
Mean
St.dev.
1970−2012
(b)
Oct
Nov
Dec
Jan
Feb
Mar
2005; 10.3
1992; −9.2
Mean = −1.0
Mean = −14.9
2011; −10.5
2002; −19.9
Mean = −21.1
2006; −14.2
1978; −28.0
Mean = −20.0
1989; −13.7
1987; −31.0
Mean = −13.0
2011; −5.8
1985; −20.4
1996; 16.6
1988; −5.2
Mean = 4.3
Energy balance (kWh/m2month)
Year

Parameters used for glazings in the current work.

Name	Source	g	U_g	g/U_g	$f \cdot g$	$f \cdot g/U_g$
G1	[23]	0.47	0.40	1.18	0.34	0.85
G2	New	0.62	0.69	0.90	0.45	0.65
G3	[23]	0.60	1.00	0.60	0.44	0.44
G4	New	0.52	0.90	0.58	0.38	0.42
G5	New	0.42	1.10	0.38	0.31	0.28

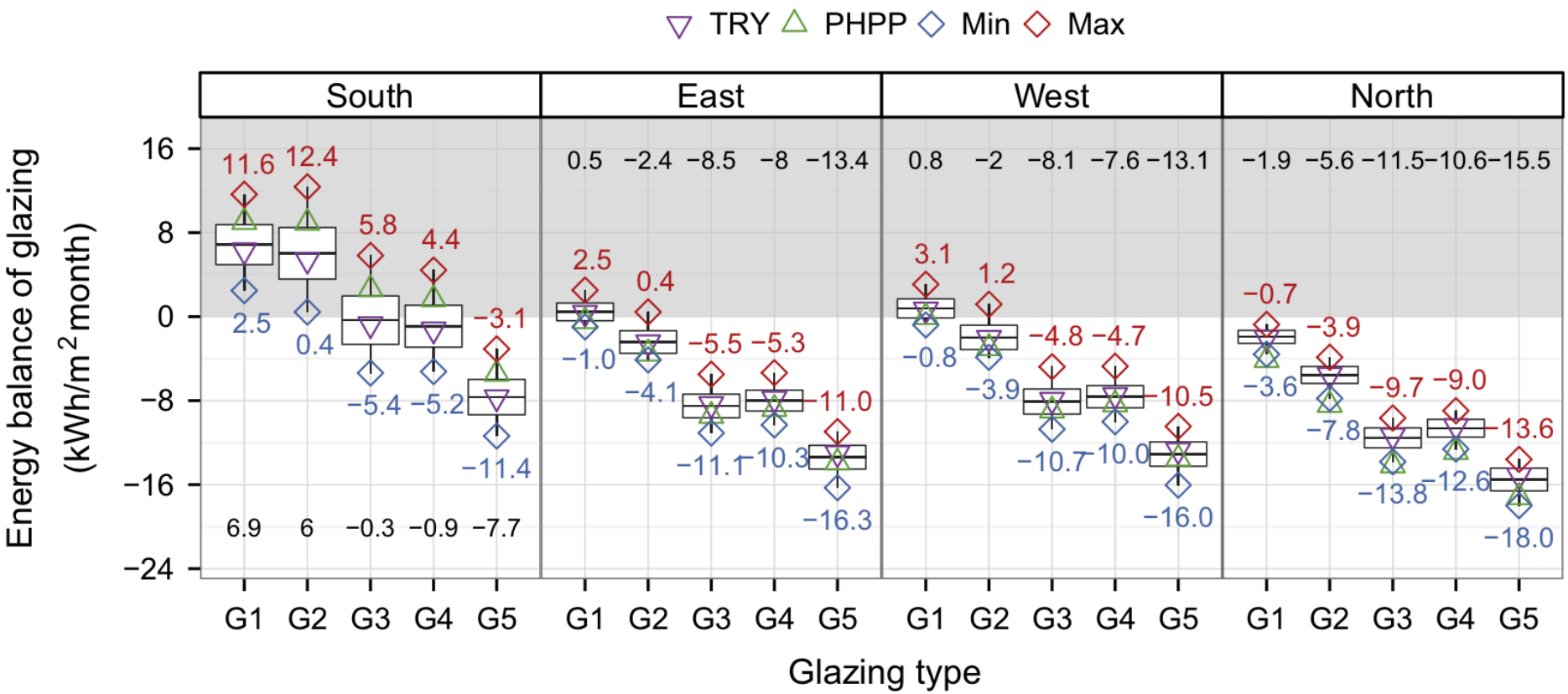


Fig. 4. The energy balance calculation results for all five glazings in the heating period.

KOKKUVÕTE

- Positiivne soojusbilanss kütteperioodi kohta tervikuna on võimalik vaid väga heade klaaspakettide/raamide ja paigalduse korral ning **lõunasse** suunatud akna puhul

- Üksikutel kuudel kütteperioodi alguses ja lõpus on positiivne soojusbilanss võimalik ka **ida- ja läänesuunalistel** akendel.

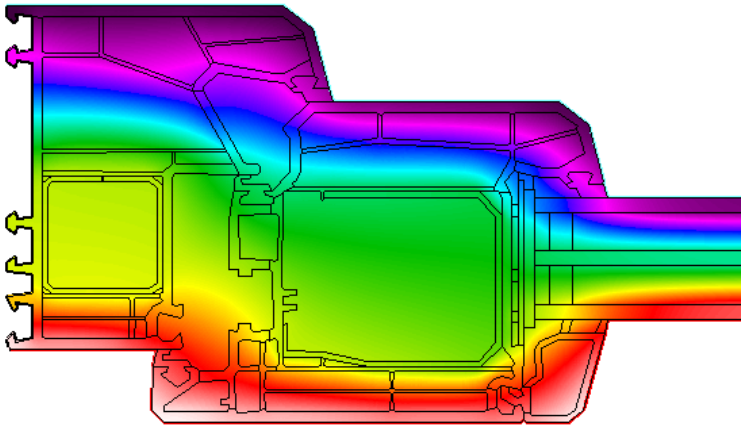
- Positiivse soojusbilansi saavutamisel on oluline akende fragmenteerituse minimeerimine ning pindalaliste omadustega mitte seotud mõjutegurite (külmasillad/ õhupidavus) oluline vähendamine!

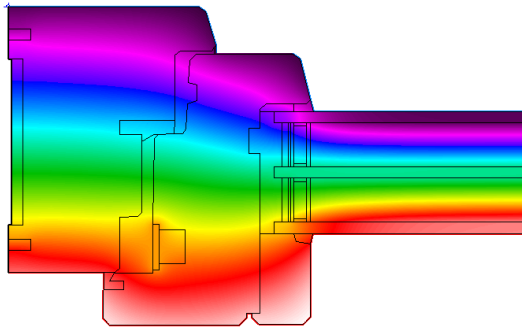
OLULISED MÕJUTEGURID

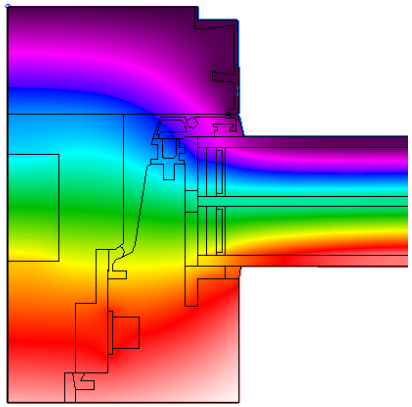
Aknaraami soojusjuhtivus

Tüüpiliselt vahemikus:

- Uf = 2,5 … 5,0 W/(m2K) – Kehv plastraam / soojuskatkestuseta alumiiniumraam
- Uf = 1,4 W/(m2K) – tüüpiline soojuskatkestuseta puitraam
- Uf = 0,6 W/(m2K) – parimad soojuskatkestusega puit ja plastraamid (EnerSign Arctics)

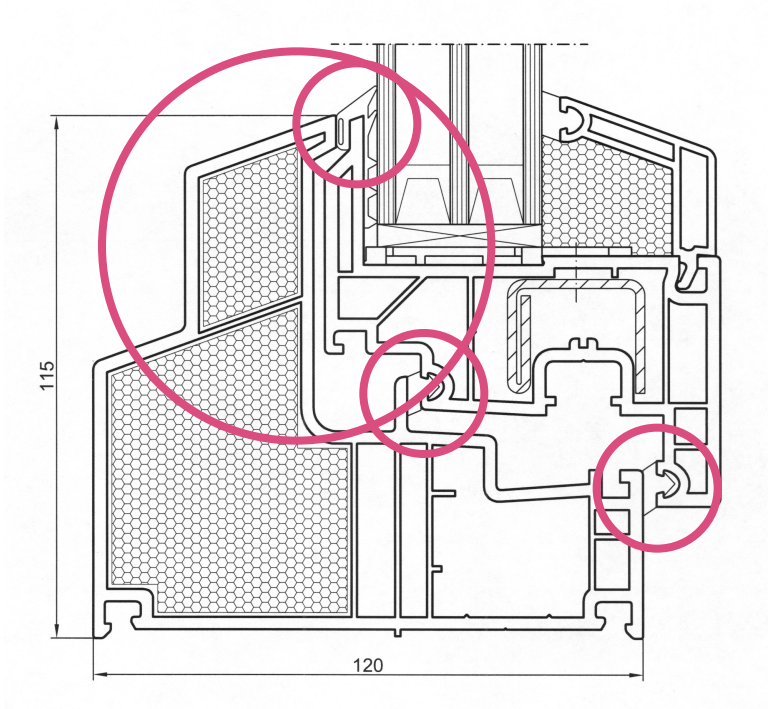






Näited tõhusatest akendest:

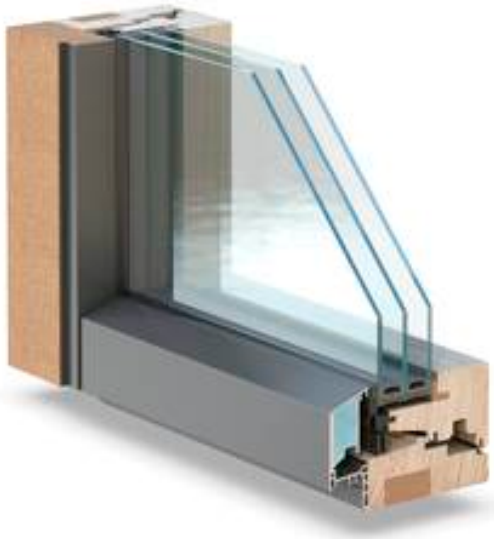
REHAU profiilsüsteem Clima-Design

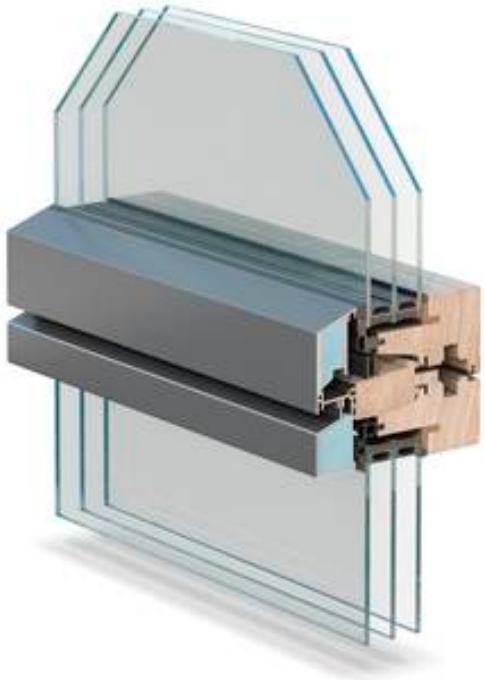


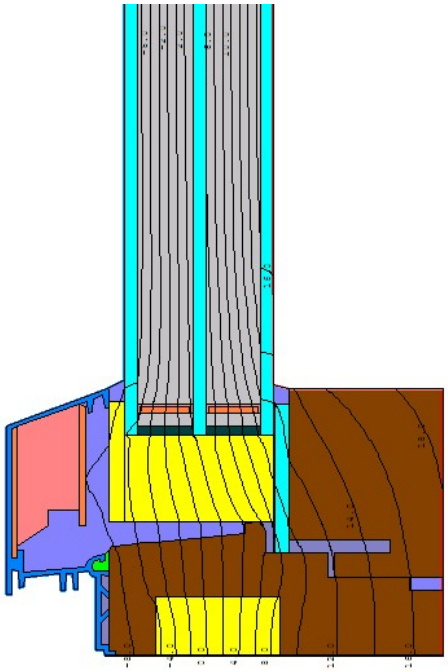
U_f = 0,71 W/(m²K)
ψ_g = 0,035 W/(mK)

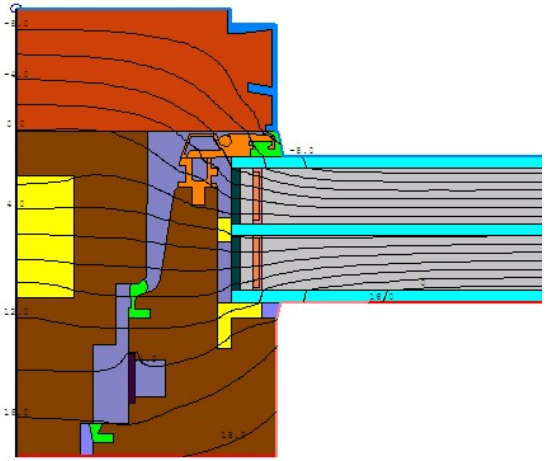
Näited tõhusatest akendest:

Smartwin (puit-alumiinium)





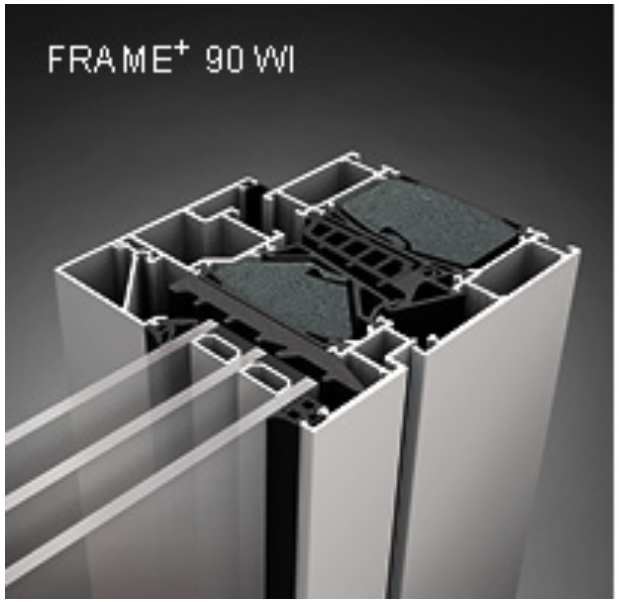


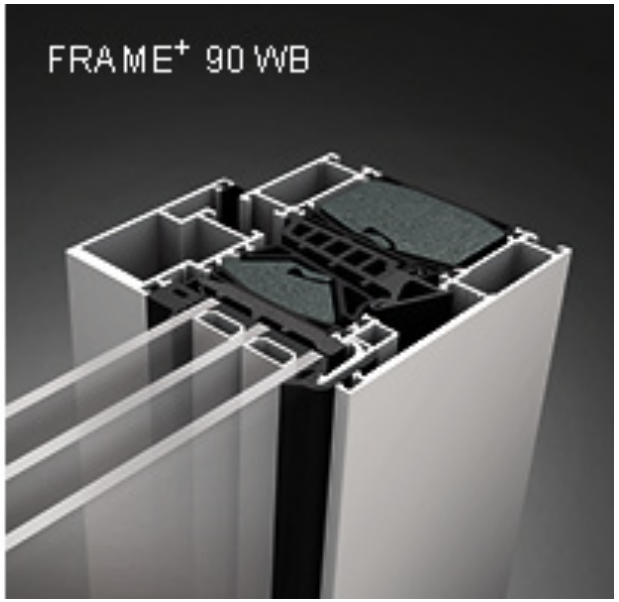


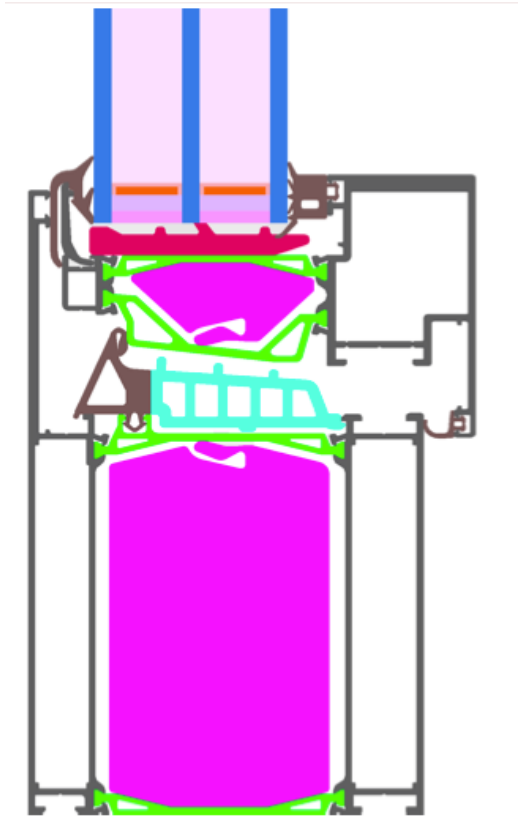
	U_f-value [W/(m²K)]	Width [mm]	Ψ_g [W/(mK)]	$f_{Rsi=0.25}$ [-]
Spacer			SwisspacerV*	
Bottom	0.91	86	0.025	0.70
Side/top	0.70	86	0.026	

Näited tõhusatest akendest:

RAICO FRAME+ 90 WB (alumiinium)





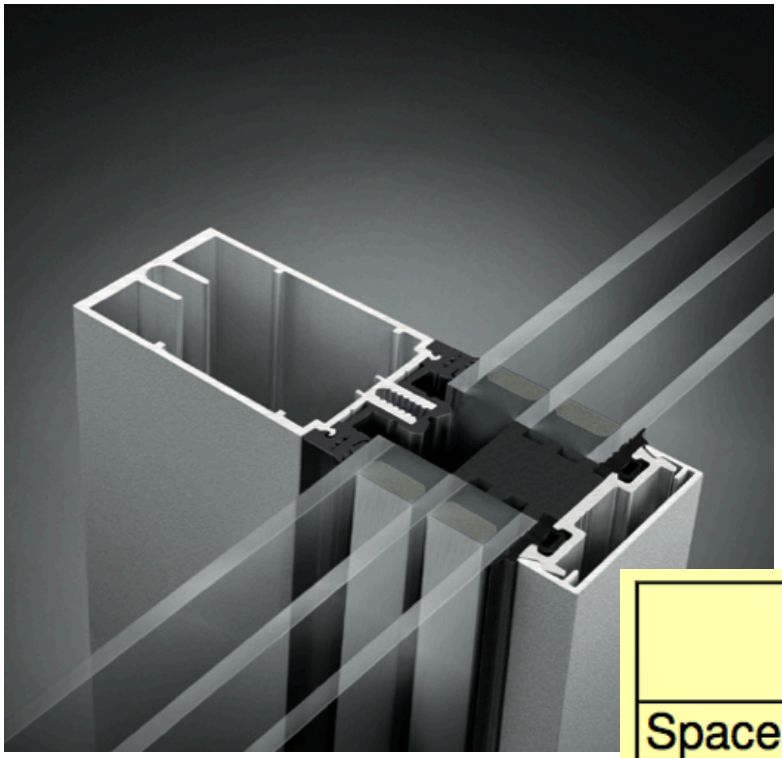


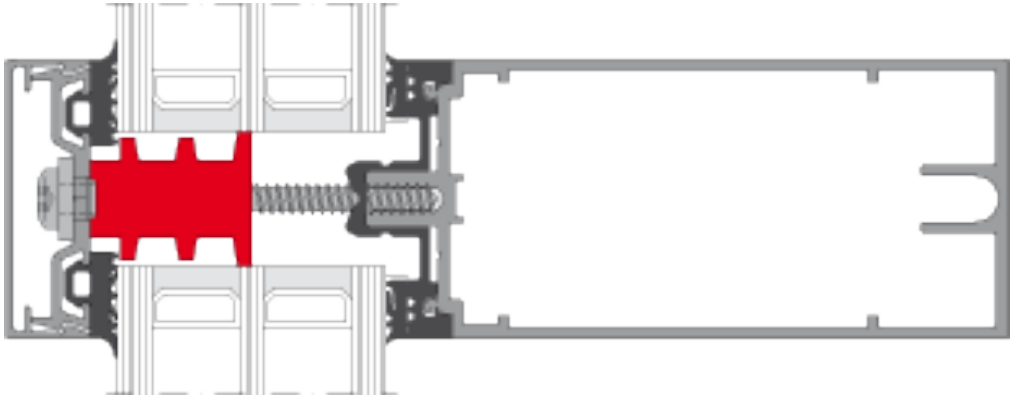
Bottom section

	U_f-value [W/(m²K)]	Width [mm]	Ψ_g [W/(mK)]	$f_{Rsi=0.25}$ [-]
Spacer			Swisspacer V*	
Bottom	0.75	159	0.032	0.75
Side/top	0.75	159	0.032	

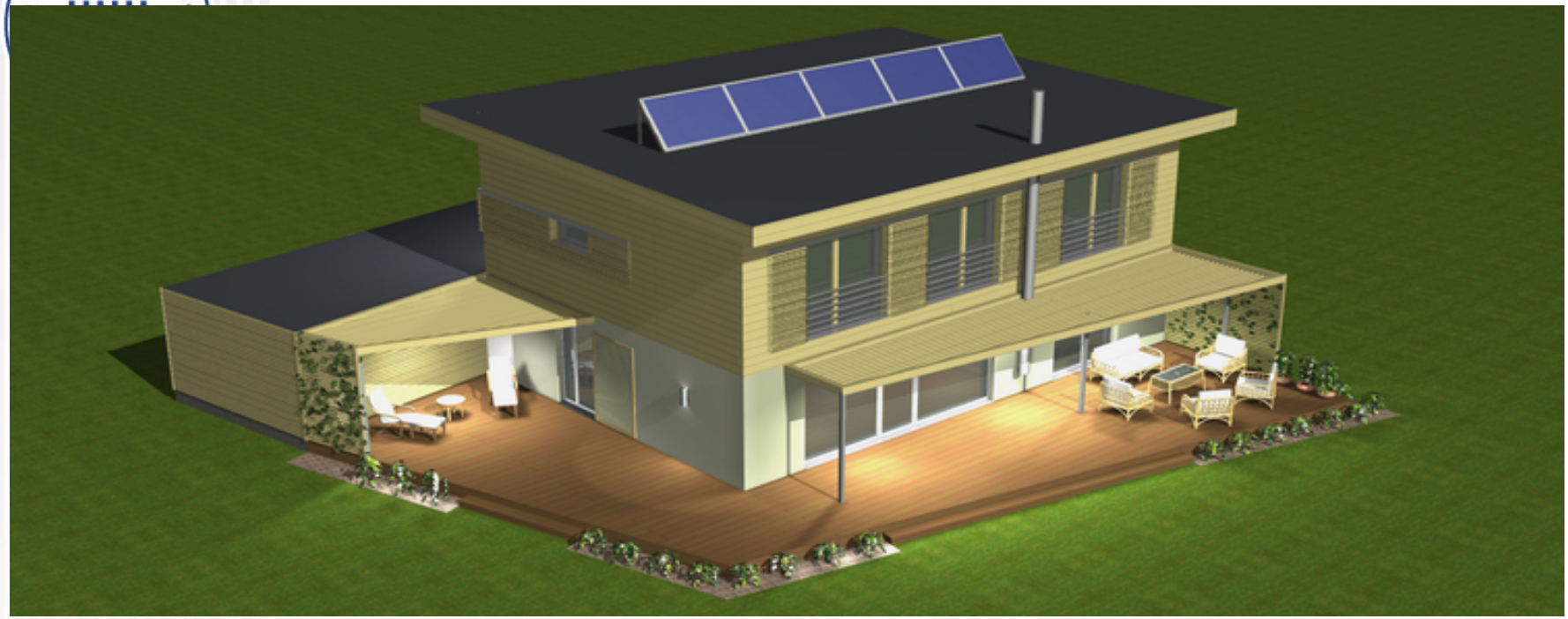
Näited tõhusatest akendest:

RAICO THERM+ 50 H-I (alumiinium)





	U_f-value [W/(m²K)]	Width [mm]	Ψ_g [W/(mK)]	$f_{Rsi=0.2}$ [-]
Spacer			Swisspacer V*	
Transom (t)	0.86	50	0.038	0.82
Mullion (m)	0.87	50	0.038	
Thermal glass carrier bridge χ_{GT} [W/K]:				0.005



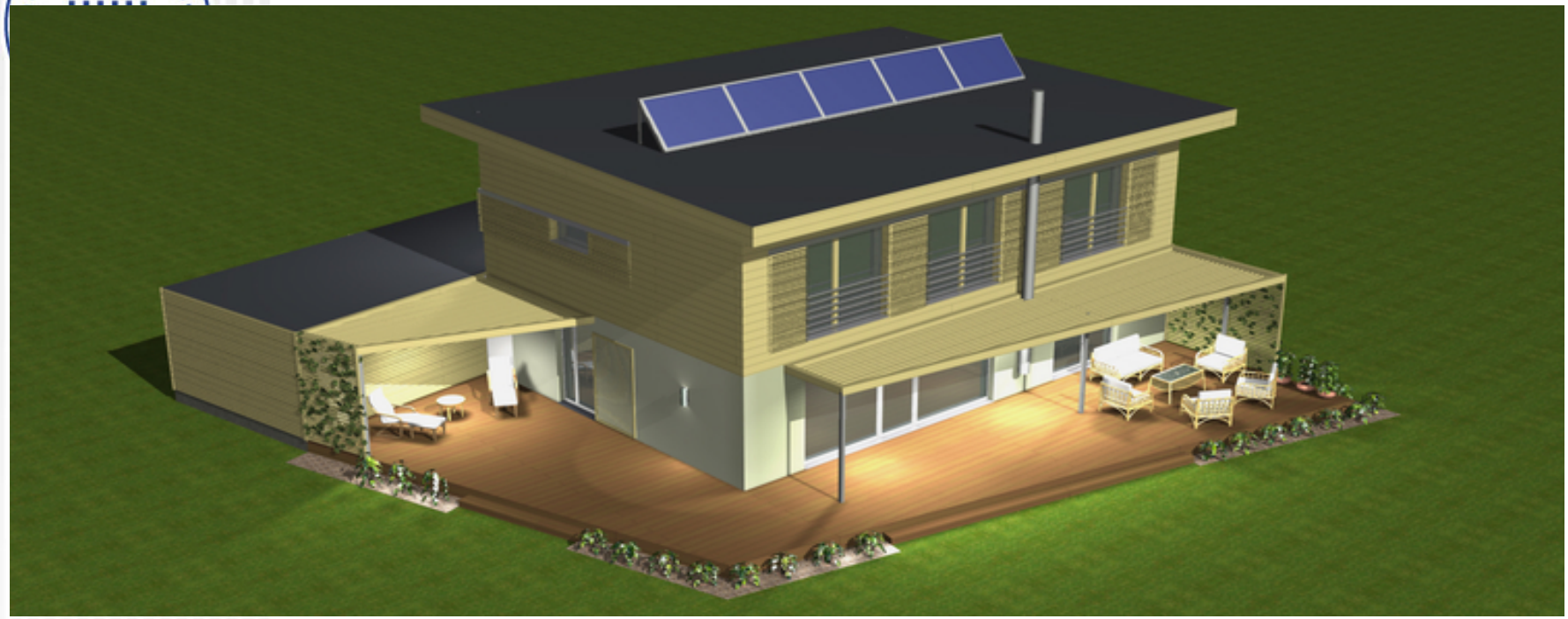
(aknaraam)	**kütteenergia netovajadus, kWh/(m2a)**	**Energiatõhususarv, kWh/(m2a)**
Uf= 2,5 W/(m2K)	31,4	118,3
Uf= 1,4 W/(m2K)	22,7	108,8
Uf=0,6 W/(m2K)	14,8	100,0

Klaaspaketi soojusläbivus

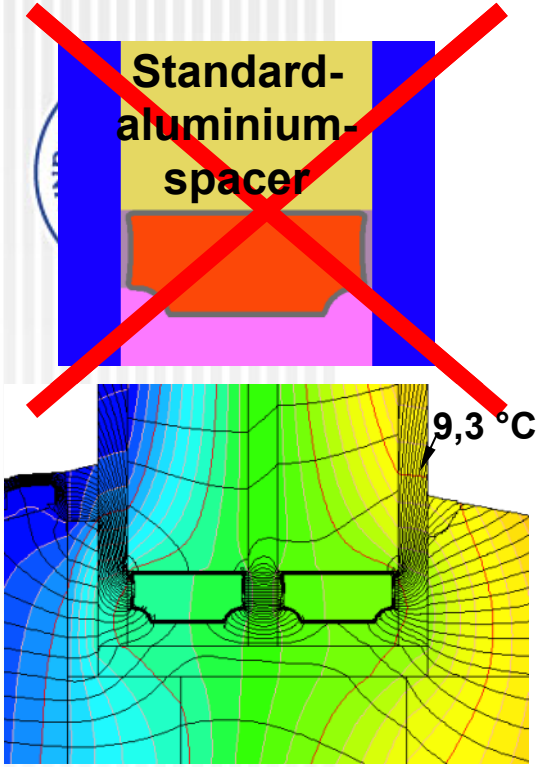
Tüüpiliselt vahemikus:

- Ug = 3,0 W/(m2K) – 2x klaaspakett õhkvahega (tavaklaasid)
- Ug = 1,1 … 1,3 W/(m2K) – 2x klaaspaket + Ar + low-e
- Ug = 0,6 … 0,7 W/(m2K) – 3x klaaspakett + Ar + 2x low-e
- Ug = 0,5 W/(m2K) – 3x klaaspakett + Kr + 2x low-e
- Ug < 0,5 W/(m2K) – eksperimentaalsed klaasingud (4x, multifoil, vaakumklaasing)

Allikas: Rehau	Täitegaas	Klaasikihtide vahekaugus	U_g (W/m²K)	SHGC
Kaheklaasiline klaaspakett	Õhk	12 mm	3,0	0,77
	Argoon	16 mm	1,1 (low-e)	0,62
	Krüptoon	12 mm	1,0 (low-e)	0,62
Kolmeklaasiline klaaspakett	Argoon	2 x 16 mm	0,6 (low-e)	0,50
	Krüptoon	2 x 12 mm	0,5 (low-e)	0,50

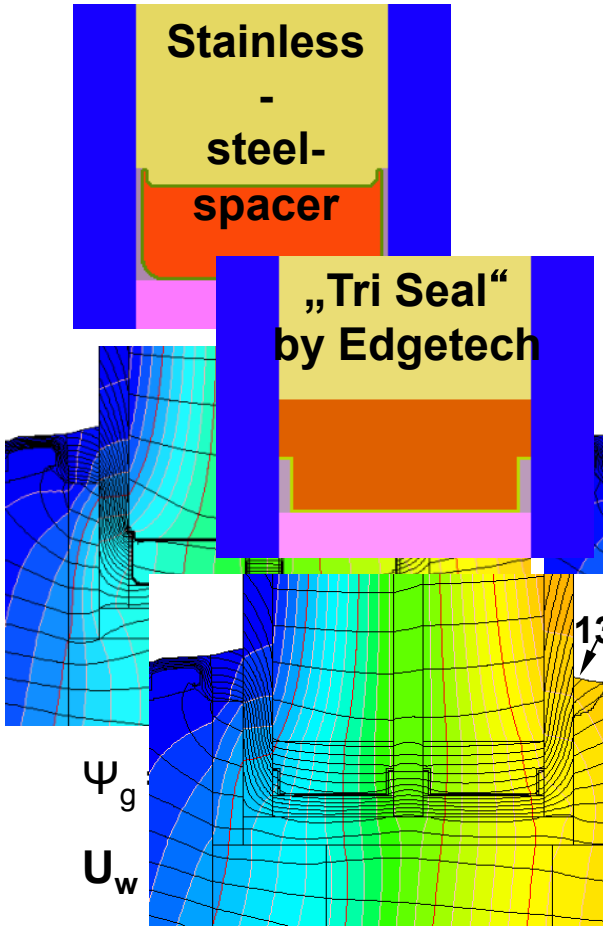


(klaaspakett)	**kütteenergia netovajadus, kWh/(m2a)**	**Energiatõhususarv, kWh/(m2a)**
Ug = 3,0 W/(m2K)	59,7	149,1
Ug = 1,1 W/(m2K)	23,1	109,1
Ug=0,6 W/(m2K)	16,2	101,6



Ψ_g = 0.076 W/(mK)

U_w = 0.89 W/(m²K)

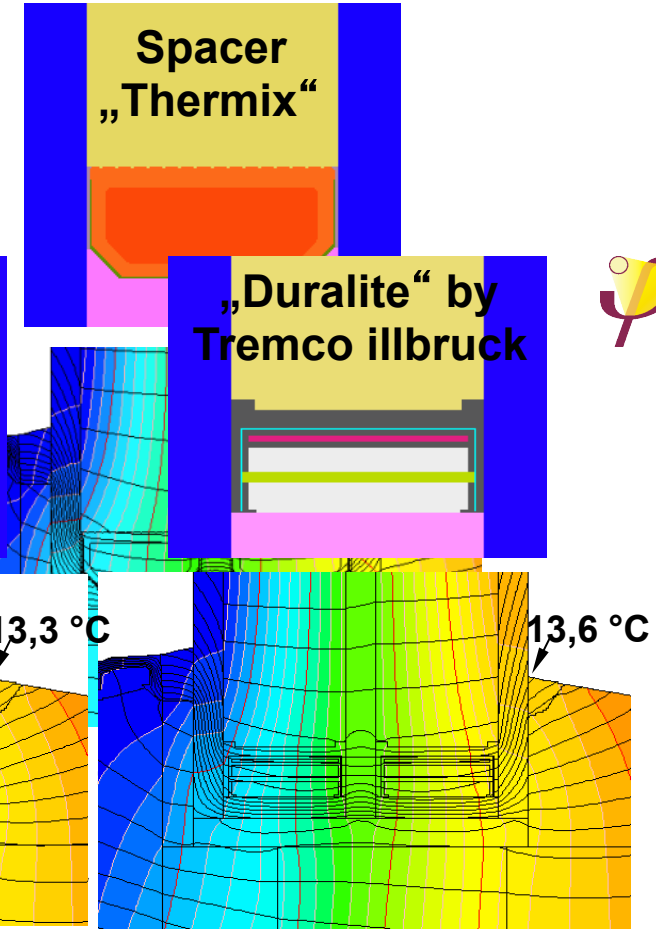


Ψ_g

U_w

Ψ_g = 0.030 W/(mK)

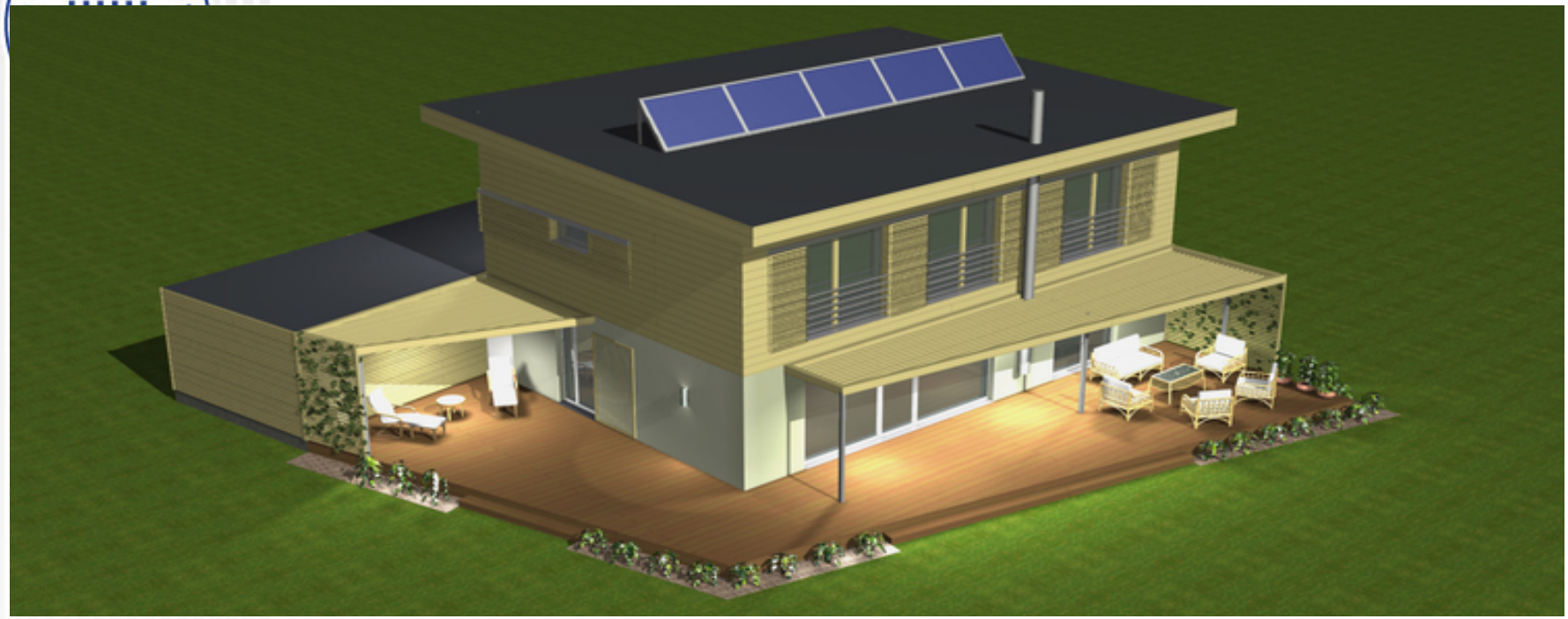
U_w = 0.78 W/(m²K)



Ψ_g = 0.027 W/(mK)

U_w = 0.77 W/(m²K)

Akna arvutuslik soojusläbivus, kui U_g = 0.70 W/(m²K), $U_{f,bottom}$ = 0.73 W/(m²K) ja $U_{f,side/top}$ = 0.70 W/(m²K)



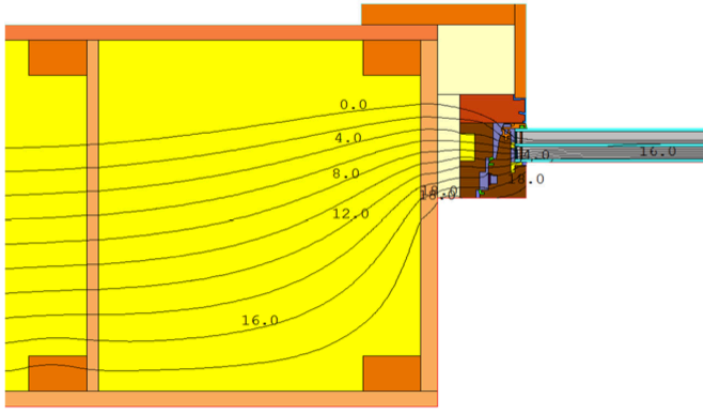
(vaheliist)	**kütteenergia netovajadus, kWh/(m2a)**	**Energiatõhususarv, kWh/(m2a)**
ψ_g= 0,076 W/(mK)	(alumiinium) 18,4	103,9
ψ_g= 0,054 W/(mK)	(teras) 17,2	102,6
ψ_g= 0,030 W/(mK)	(plastik-komposiit) 15,9	101,2

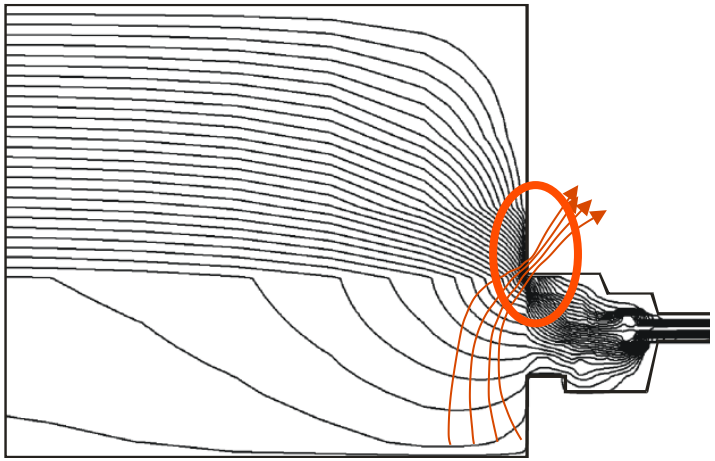
Akna seinakinnituse joonsoojusläbivus

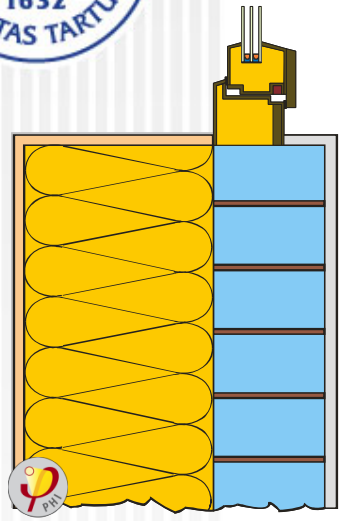
Võib olla sõltuvalt lahendusest väga olulise mõjuga. **Suur potentsiaal optimeerimiseks**.

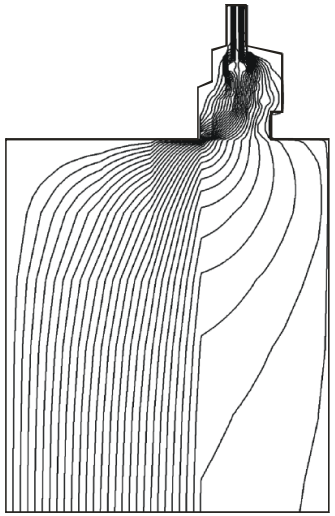
<u>Tüüpiliselt vahemikus:</u>

- ψ = > 0,2 W/(mK) – soojuslikult väga halb lahendus
- ψ = < 0,02 … 0,04 W/(mK) – soojuslikult hea tüüpahendus
- ψ = < 0 W/(mK) – paks ülekate, soojuslikult ülioptimeeritud lahendused



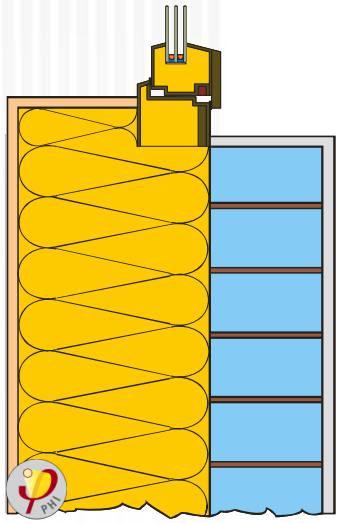


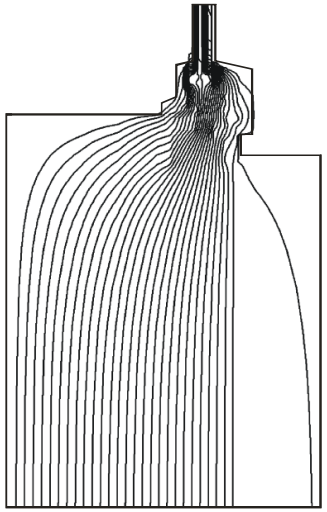




$\Psi_{install}$ = 0.15 W/(mK)

$U_{w,eff}$ = 1.19 W/(m²K)

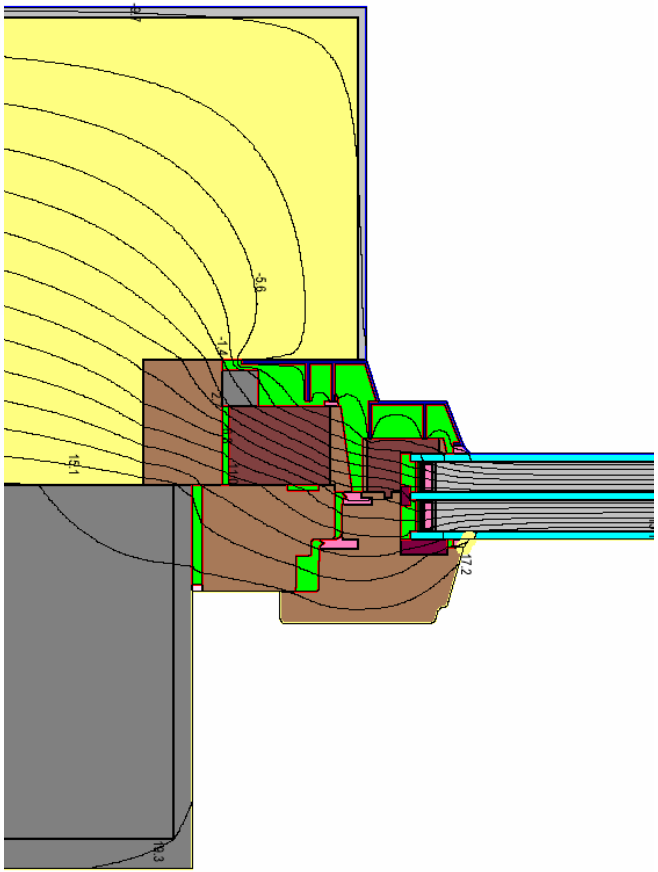


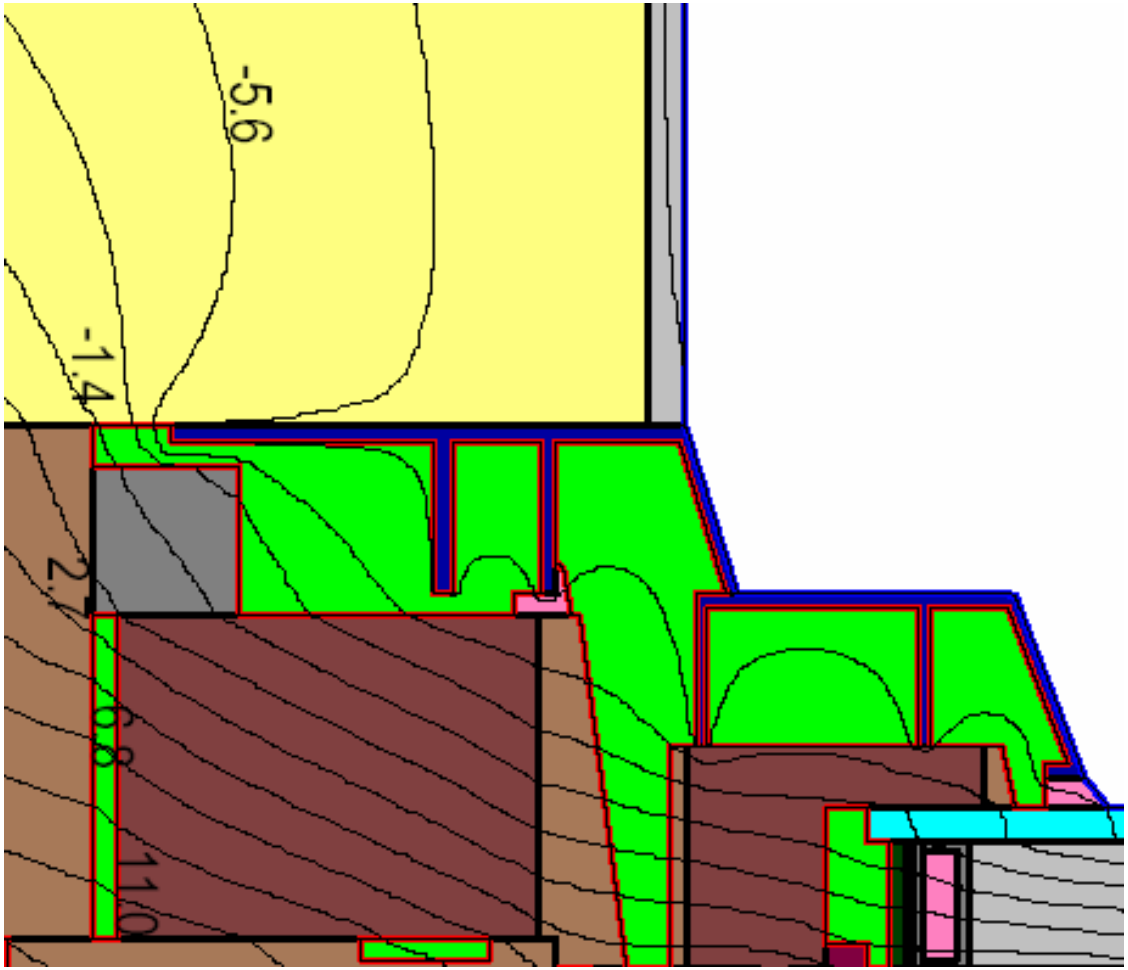


$\Psi_{install}$ = 0.005 W/(mK)

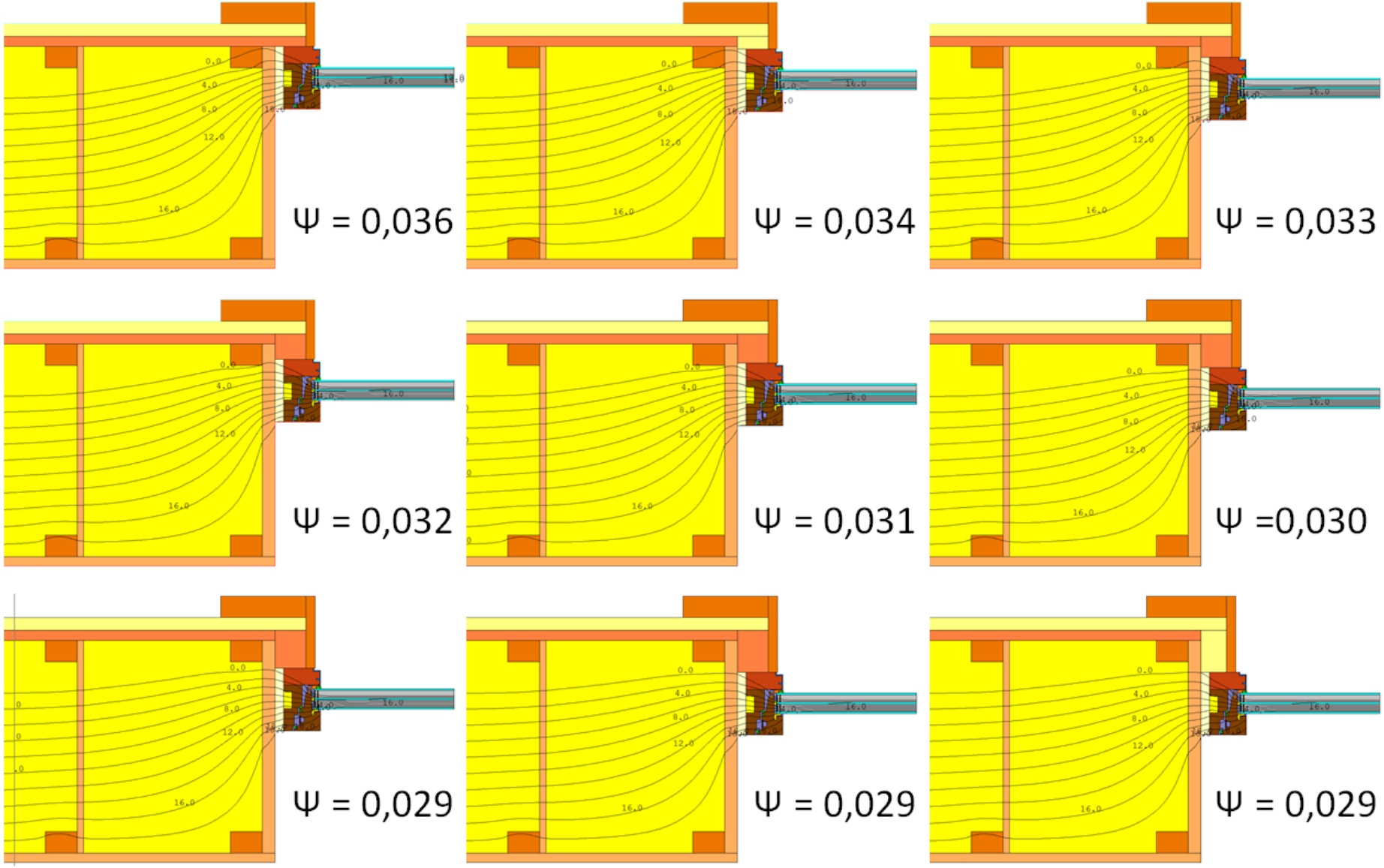
$U_{w,eff}$ = 0.78 W/(m²K)

Erisus tavapäraste puit-alumiiniumakende korral

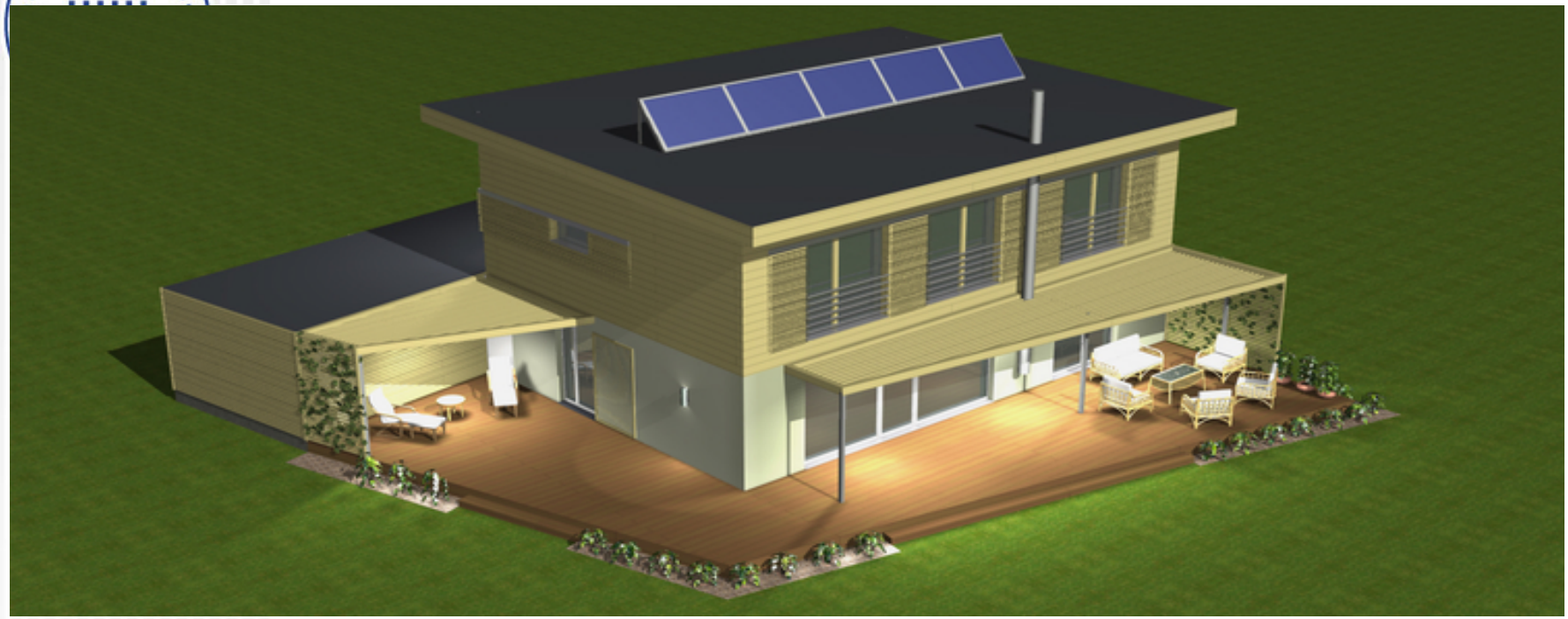




Ψ_{Einbau} = 0.06 W/(mK)

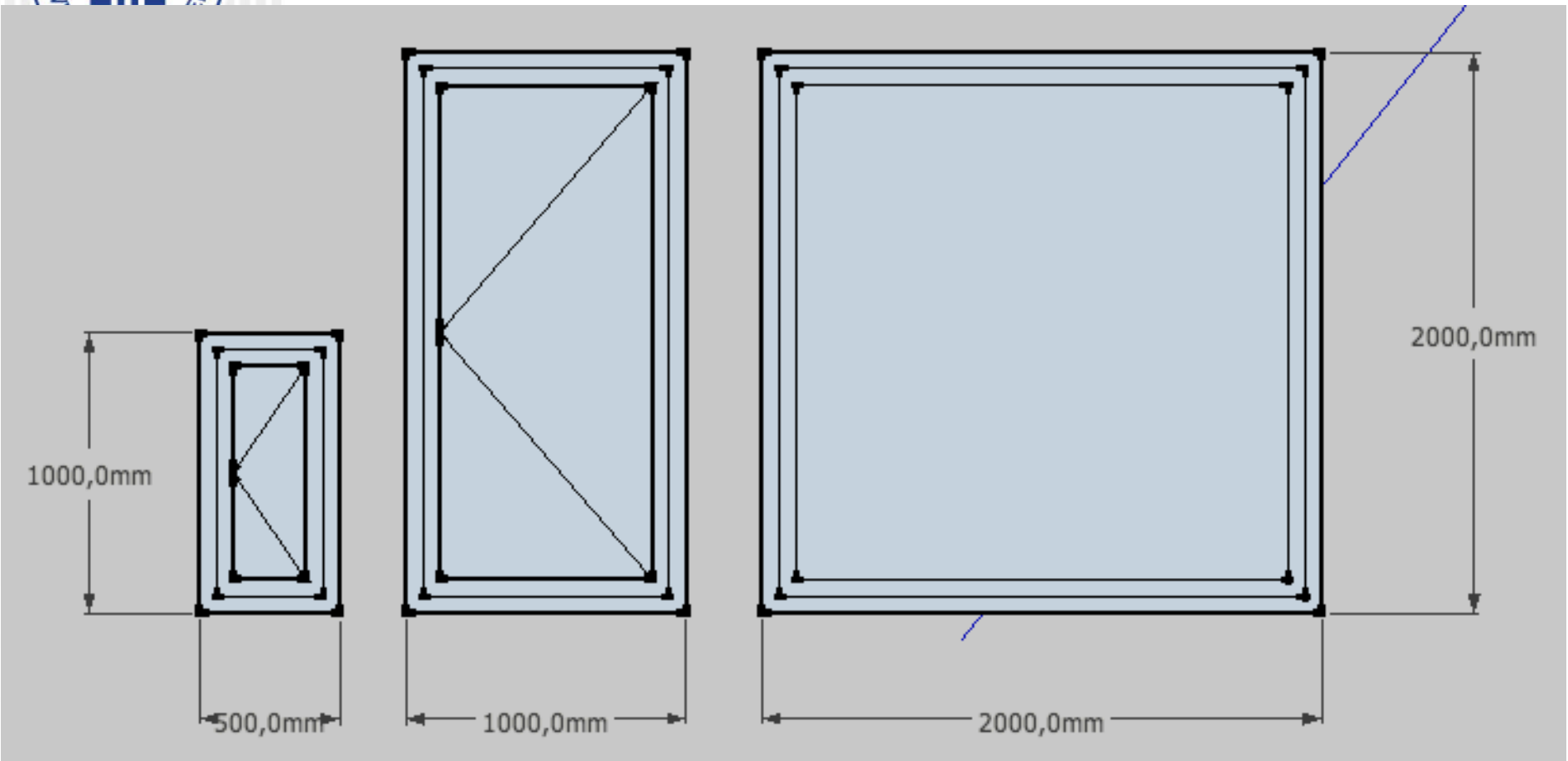


Akna seinakinnituse optimeerimine



	kütteenergia netovajadus, kWh/(m2a)	Energiatõhususarv, kWh/(m2a)
Ψ = 0,20 W/(mK)	24,0	110,1
Ψ = 0,03 W/(mK)	16,1	101,5
Ψ = 0,00 W/(mK)	14,9	100,1

Eeltoodud parameetrite mõju suurus oleneb oluliselt akna suurusest ja/või avatäidete fragmenteeritusest



	laius	kõrgus	raami/lengi kõrgus	S_aken	S_raam	S_klaas	klaasi %
väike	0,5	1	0,12	0,5	0,30	0,20	40%
keskmine	1	2	0,12	2	0,66	1,34	67%
suur	2	2	0,12	4	0,90	3,10	77%

Energiaarvutusteks olulisi tähelepanekuid

Lähteandmete piisav kirjeldamine. Aknakomponentide variatsiooni mõju võib olla sõltuvalt projektis suur, **eeskätt madalenergia ja liginullenergia hoonete** korral. Seega:

- Oluline on arvutusmudelis eelnevalt käsitletud parameetrid detailselt kirjeldada (need on spetsiifilised üksikule avale):
  - klaasi ja raamiosa soojusläbivus eraldi
  - raami mõõtmed (osakaal),
  - joonkülmasildade pikkused ja joonsoojusjuhtivused,
  - **Varjutusolud!** (lihtsustatud arvutustarkvarad)

Palavusriski ja päikesekaitsevajaduse hindamine on oluline!

- Tuulutuse võimalik mõju
- Erinevate päikesekaitselahenduste mõju

Tänan tähelepanu eest!