Insulating Dutch Row Houses

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Abstract

Dutch buidling regulations over the past decades gradually increased the insulation and ventilation requirements. This presentations shows a simplified model fo a Ducth row house to understand the effect of insulation on energy consumption, energy label, and energy costs.

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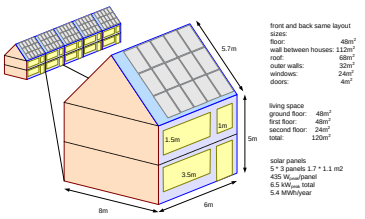
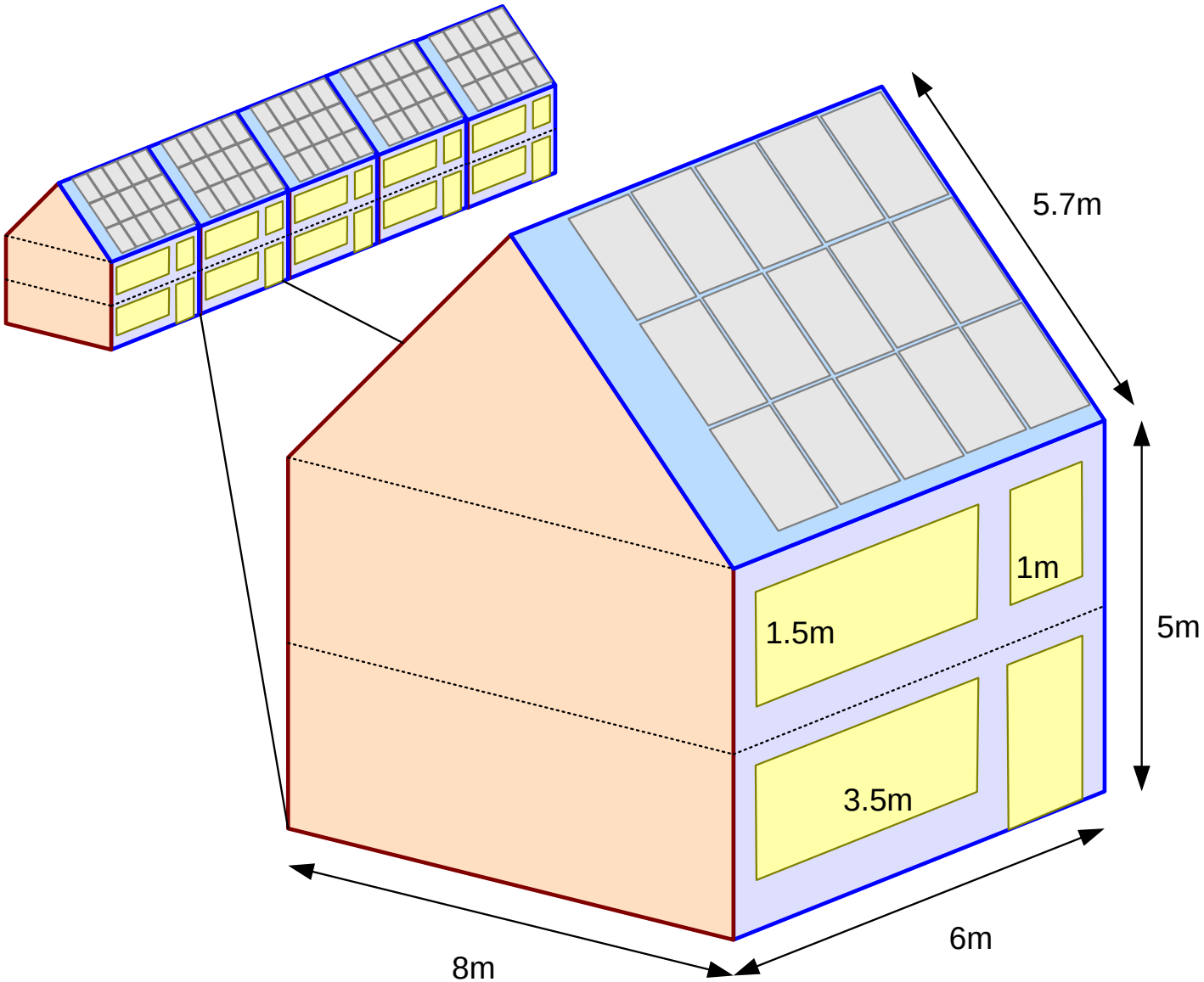
version: 0



Case: a Simplified Row House



front and back same layout

sizes:

floor:	48m^2
wall between houses:	112m^2
roof:	68m^2
outer walls:	32m^2
windows:	24m^2
doors:	4m^2

living space

ground floor:	48m^2
first floor:	48m^2
second floor:	24m^2
total:	120m^2

solar panels

5 * 3 panels 1.7 * 1.1 m2

435 W_{peak}/panel

6.5 kW_{peak} total

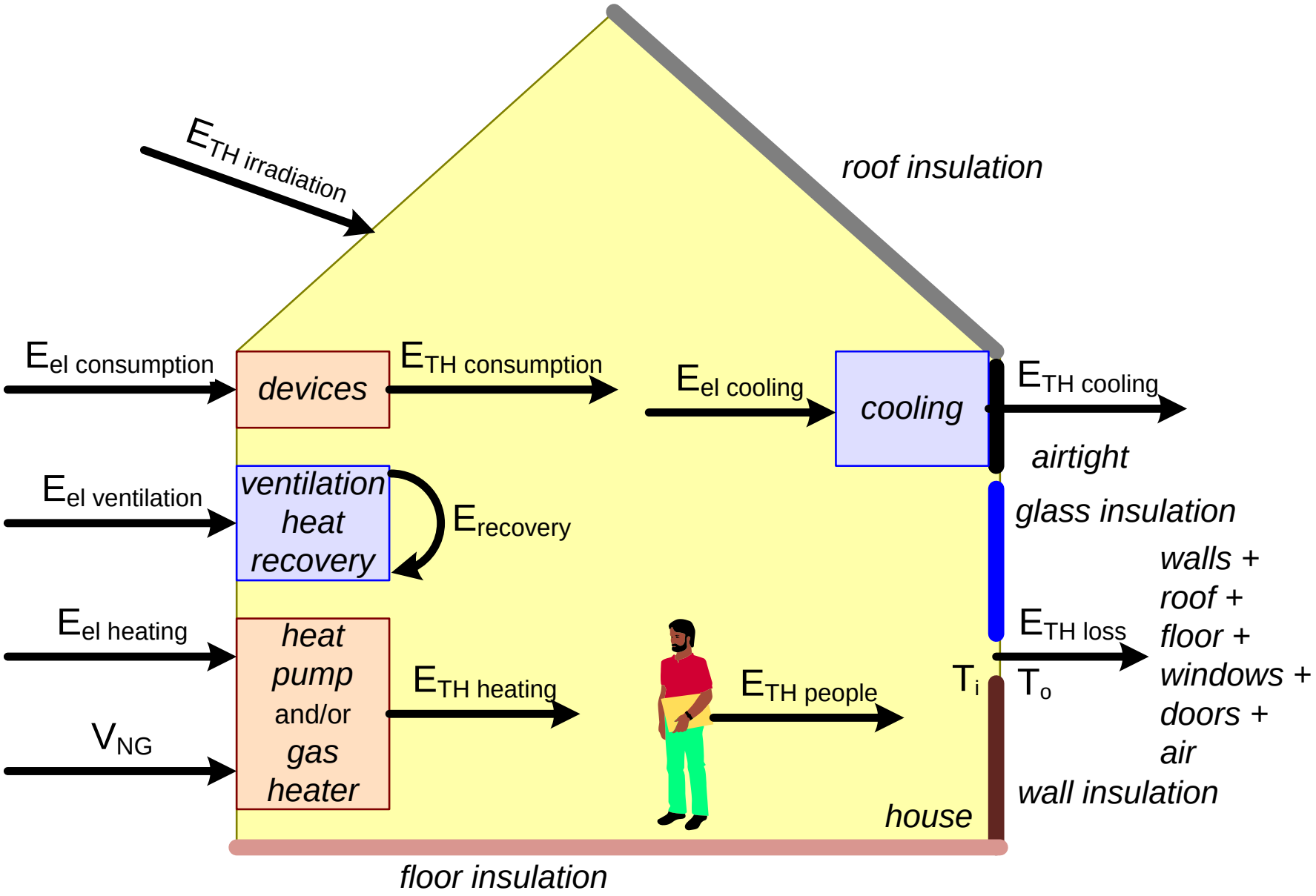
5.4 MWh/year

All Based on a Highly Simplifed Model

model simplifications and assumptions

- This is a zero-order model, e.g.
  - only the main contributors
  - assuming linearity (or even constantness)
- simplified orientation (North-South)
- averaged climate conditions (based on Eindhoven)
- averaged (assumed) environmental conditions (e.g. some shadow)
- only the energy balance (incoming and outgoing energy)
- heat capacity is ignored
- irradiation only taking windows into account
- direct use of Rc and U values
- internal house temperature 21^{o}C entire year
- coarse estimates for air leaks and ventilation
- generated solar energy compensates for used thermal energy for the label
- warm water and other electricity use not yet included in energy costs
  - except for electricity price when delivering back solar energy

Incoming and Outgoing Energy Flows



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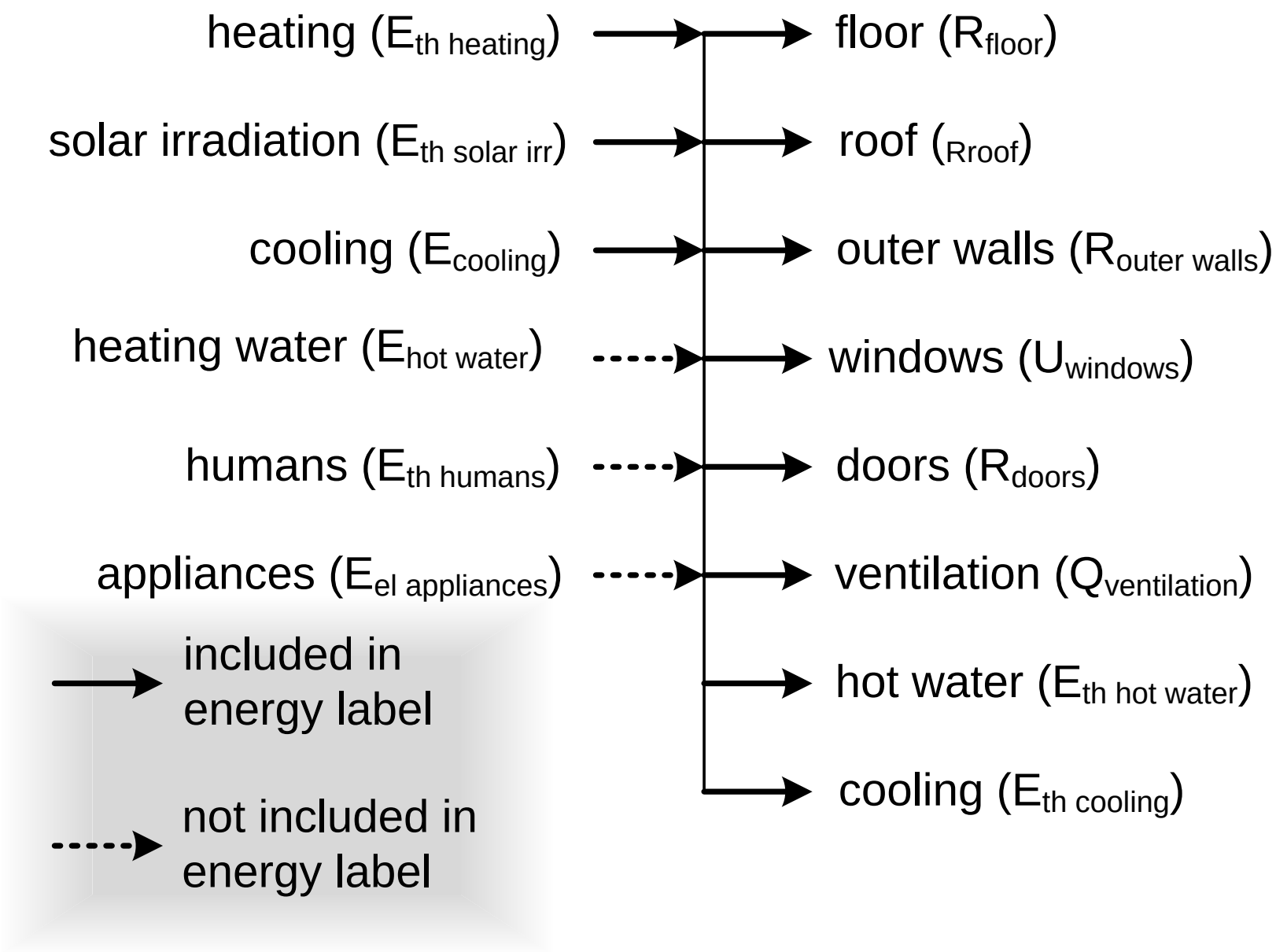


Insulation Data

insulation formulas

thermal resistance:

$R = d / \lambda$ [m^2K/W]

$U = 1 / R$ [W/m^2K]

insulation requirements residential

before 1981	0.4	
1981-1987	1.3	~ 4 cm glass wool
1987-1992	2.0	~ 6 cm glass wool
1992-2007	2.5	
2007-2015	3.5	~ 8 cm PUR
since 2015	4.5	~ 10 cm PUR
not yet	8	~ 20 cm PUR

R_c in m^2K/W

from: Joost Muller
Veldhoven Duurzaam

insulation materials

material	W/m^2K λ	m^2K/W R_{5cm}
PUR (wall)	0.023	2.2
PUR (roof)	0.028	1.8
glass wool	0.035	1.43
wood	0.18	0.28
concrete/stone	1.5	0.03

https://bouw-energie.be/nl-be/bereken/r-waarde-isolatie

glass insulation

glass	W/m^2K U	m^2K/W R_{glass}
single	5.8	0.18
double	2.8	0.33
double HR++	1.1	0.83
triple HR++	0.5	1.6

https://glasherstelhermans.nl/isolatiewaarde-glas/

Climate Eindhoven Data

	days / month	hours / month	$T_{in} = 21^{o}C$ $T_{average}$	Delta T	g_{year}	solar irradiation	angle	kWh/ m^2/ month
jan	31	744	3.6	17.4	12946	21	17.2	10.2
feb	28	672	3.9	17.1	11491	38	24.9	17.4
mar	31	744	6.5	14.5	10788	76	36	30.7
april	30	720	9.9	11.1	7992	118	48	39.5
may	31	744	13.4	7.6	5654	153	57.3	41.3
jun	30	720	16.2	4.8	3456	156	61.5	37.2
jul	31	744	18.3	2.7	2009	155	59.5	39.3
aug	31	744	17.9	3.1	2306	133	51.6	41.4
sep	30	720	14.7	6.3	4536	91	40.2	34.6
oct	31	744	10.9	10.1	7514	55	28.3	24.2
nov	30	720	7	14.0	10080	26	19	12.2
dec	31	744	4.2	16.8	12499	16	14.9	7.7
year					91272	1038		

$T_{average}$ https://weerstatistieken.nl/eindhoven “normal” = average 1991-2020

angle https://weerman.nu/voorbeeld-pagina/zonnepanelen/zonnestand-per-maand-in-nederland/

derived from data from ROYAL NETHERLANDS METEOROLOGICAL INSTITUTE

irradiation https://www.knmi.nl/nederland-nu/klimatologie/daggegevens

Loss via Walls, Roof, Floor. Windows, and Doors

formulas

$Q_{outer\ walls} = A_{outer\ walls} / R_{outer\ walls}$ [W/K]

$Q_{roof} = A_{roof} / R_{roof}$ [W/K]

$Q_{floor} = A_{floor} / R_{floor}$ [W/K]

$Q_{windows} = A_{windows} * U_{windows}$ [W/K]

$Q_{doors} = A_{doors} / R_{doors}$ [W/K]

$E_{th\ outer\ walls} = Q_{outer\ walls} * g_{year} /1000$ [kWh/y]

$E_{th\ roof} = Q_{roof} * g_{year} /1000$ [kWh/y]

$E_{th\ floor} = Q_{floor} * g_{year} /1000$ [kWh/y]

$E_{th\ windows} = Q_{windows} * g_{year} /1000$ [kWh/y]

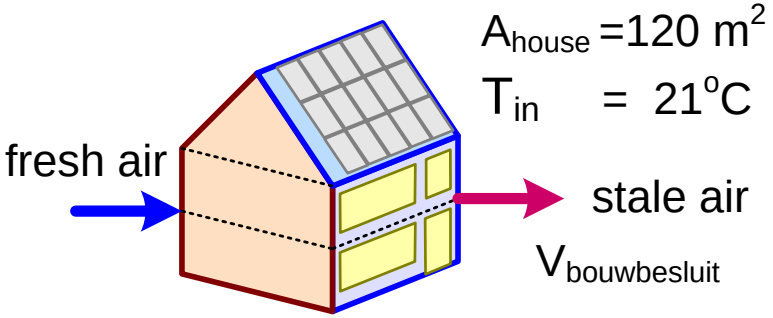
$E_{th\ doors} = Q_{doors} * g_{year} /1000$ [kWh/y]

example poorly insulated row house

$R_{walls,\ floors,\ roof}$	m^2K/W	0.4	
$U_{windows}$	W/m^2K	5.8	single
R_{doors}	m^2K/W	0.2	
$Q_{ventilation}$	W/K	100	
	m^2	Q [W/K]	$E_{thermal}$ [kWh/y]
outer walls	32	80	7302
roof	68	170	15516
floor	48	120	10953
windows	24	139	12705
doors	4	20	1825

Ventilation

heat loss due to mandatory ventilation



A_{house} =120 m^2

T_{in} = 21°C

$V_{bouwbesluit}$

ventilation data

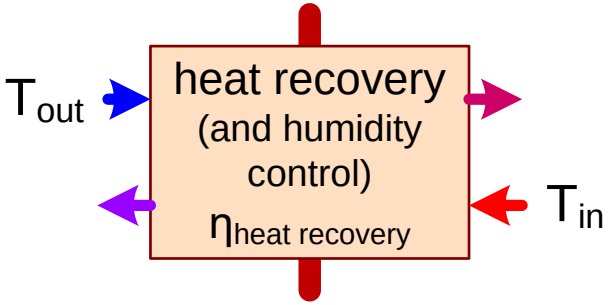
$V_{bouwbesluit}$ [1] = 2.24 $m^3\ m^{-2}\ h^{-1}$

$C_{heat\ air}$ [2] = 918 J $m^{-3}\ K^{-1}$

$Q_{ventilation}$ = 0.83 W $m^{-2}\ K^{-1}$

$\eta_{heat\ recovery}$ [3] = 90%

heat recovery



row house ventilation data

g_{year} Eindhoven = 91272 K h y^{-1} [A]

no HR $E_{th\ ventilation}$ = 120 * 0.83 * 91272

= 9127 kWh y^{-1}

$C_{ventilation}$ = 10% [B]

with smart HR $E_{th\ ventilation}$ = 120 * 0.83 * 0.1 * 0.1 * 91272

= 91 kWh y^{-1}

[A] IDRHclimateEindhoven

[B] (1/4 of the space, 1/3 of the time)

ventilation formula

$Q_{ventilation} = C_{heat\ air} * V_{bouwbesluit}$

$\Delta T = T_{in} - T_{out}$

$g_{year} = \sum_{month} \Delta t_{month} * n_{hours\ month}$ (“graaduren”)

$E_{th\ ventilation} = A_{house} * Q_{ventilation} * C_{ventilation} * (1 - \eta_{heat\ recovery}) * g_{year}$

sources

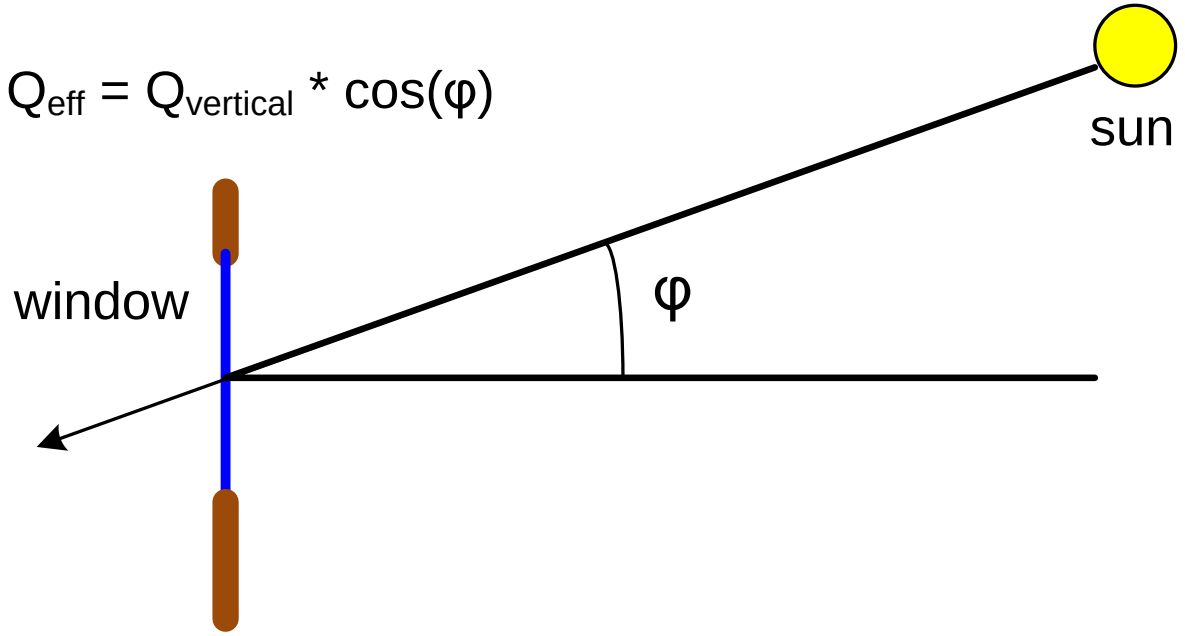
[1] https://www.cvtotaal.nl/blog/post/wtw-capaciteit-berekenen

[2] https://www.bit.nl/news/88/468/De-zin-en-onzin-van-luchtbevochtiging

[3] https://www.thermografiekeur.nl/binnenklimaat/ventilatie/

Heating Due to Solar Irradiation

$Q_{eff} = Q_{vertical} * \cos(\varphi)$



$Q_{eff} = \sum \cos(\varphi_{month}) * Q_{irradiation\ month}$

$A_{eff\ windows} = \sum A_{window} * c_{orientation} * c_{shadow}$

$E_{heating} = A_{eff\ windows} * Qeff * T_{window} *$

$c_{orientation} = 50\%$

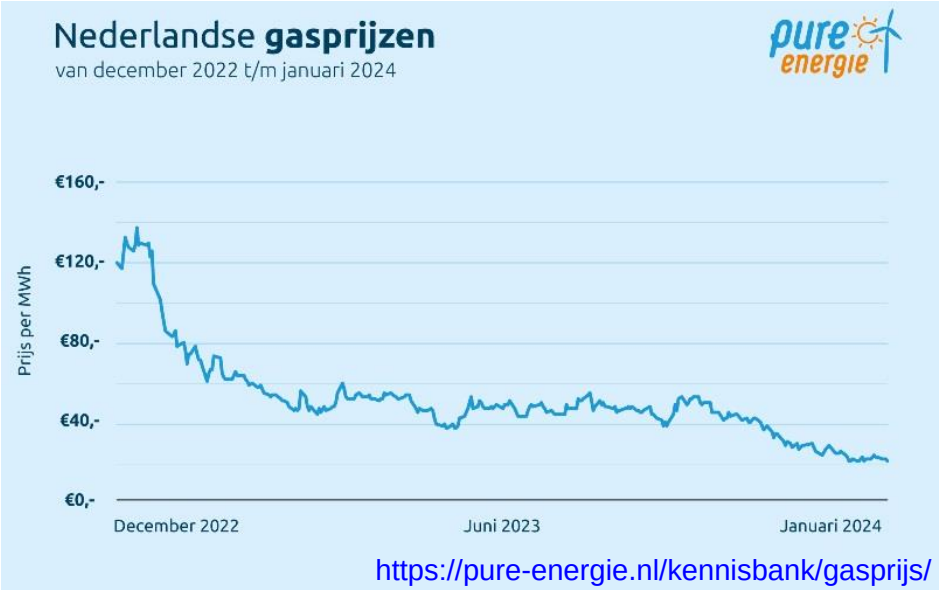
$c_{shadow} = 50\%$

$T_{single\ glass} = 85\%$

$T_{double\ glass} = 75\%$

https://www.joostdevree.nl/shtmls/reflectie-absorptie-transmissie.shtml

Energy Price Data



https://pure-energie.nl/kennisbank/gasprijs/

https://pure-energie.nl/kennisbank/ontwikkeling-energieprijzen/

energy tax 2024

gas: 0.70544 € /m^3

0.070544 €$kWh_{thermal}$

electricity: 0.13165 €/$kWh_{electric}$

https://pure-energie.nl/kennisbank/energiebelasting/

energy prices 20240407

$gas_{consumer}$ 0.12 €$kWh_{thermal}$ incl VAT

https://pure-energie.nl/kennisbank/gasprijs/

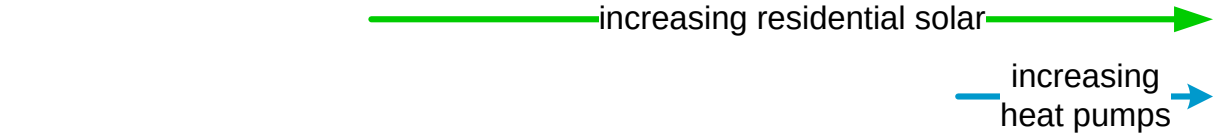
$electricity_{consumer}$ 0.263 €$kWh_{electric}$ incl VAT

$electricity_{\text{to grid}}$ 0.06 €$kWh_{electric}$ incl VAT

https://pure-energie.nl/groene-stroom/tarieven/

Evolution of Row Houses

before 1981	1981-1987	1987-1992	1992-2007	2007-2015	since 2015	not yet
gas heater	gas heater	gas heater	gas heater	gas heater	gas heater	heat pump
barely insulated	some insulation	medium insulation	medium insulation	good insulation	better insulation	well insulated
single glass	single glass	double glass	HR+ glass	HR+ glass	HR++ glass	HR+++ triple
many air leaks	airleaks	less air leaks	less air leaks	heat recovery	heat recovery	smart HR

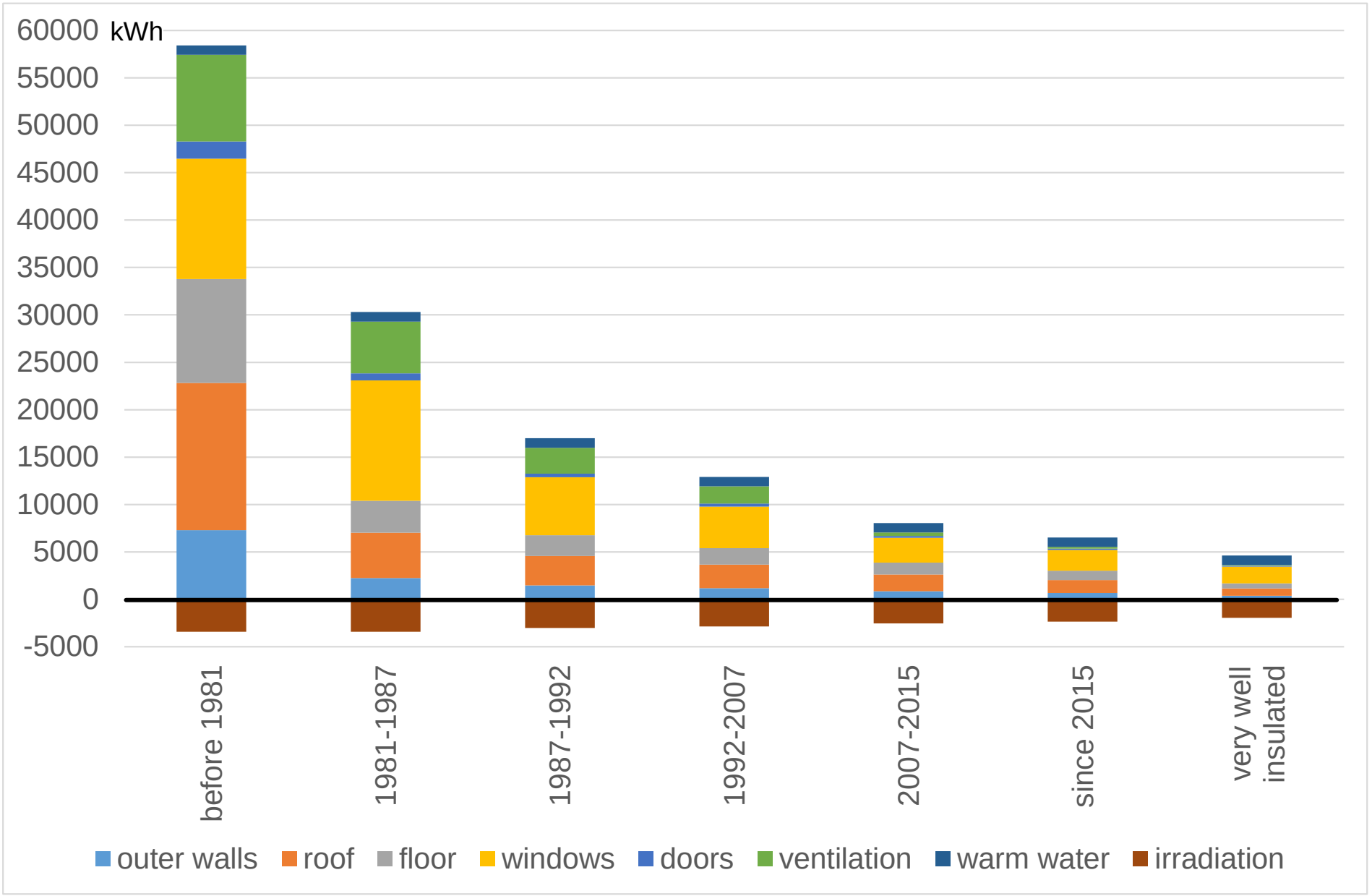


Underlying Data

	before 1981	1981-1987	1987-1992	1992-2007	2007-2015	since 2015	very well insulated
Rwalls, floors, roof	0.4	1.3	2	2.5	3.5	4.5	8
Uwindows	5.8	5.8	2.8	2	1.2	1	0.8
Rdoors	0.2	0.5	1	1.2	2	2.5	4.5
Qventilation	100	60	30	20	4	2	1

years	before 1981	1981-1987	1987-1992	1992-2007	2007-2015	since 2015	very well insulated
outer walls	7302	2247	1460	1168	834	649	365
roof	15516	4774	3103	2483	1773	1379	776
floor	10953	3370	2191	1752	1252	974	548
windows	12705	12705	6133	4381	2629	2191	1752
doors	1825	730	365	304	183	146	81
ventilation	9127	5476	2738	1825	365	183	91
warm water	1000	1000	1000	1000	1000	1000	1000
irradiation	-3424	-3424	-3019	-2858	-2559	-2363	-1949

Heat Loss Decomposition



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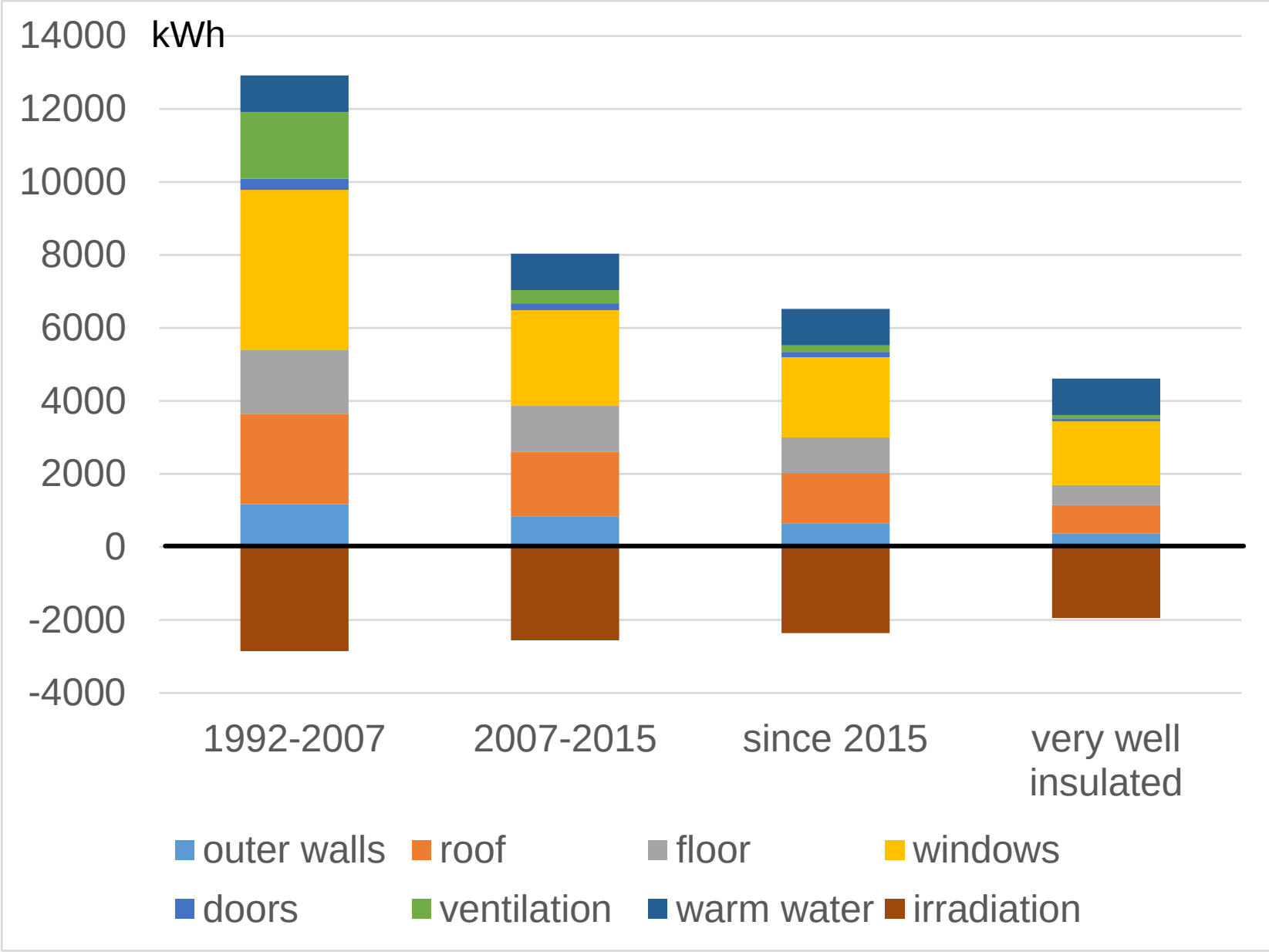
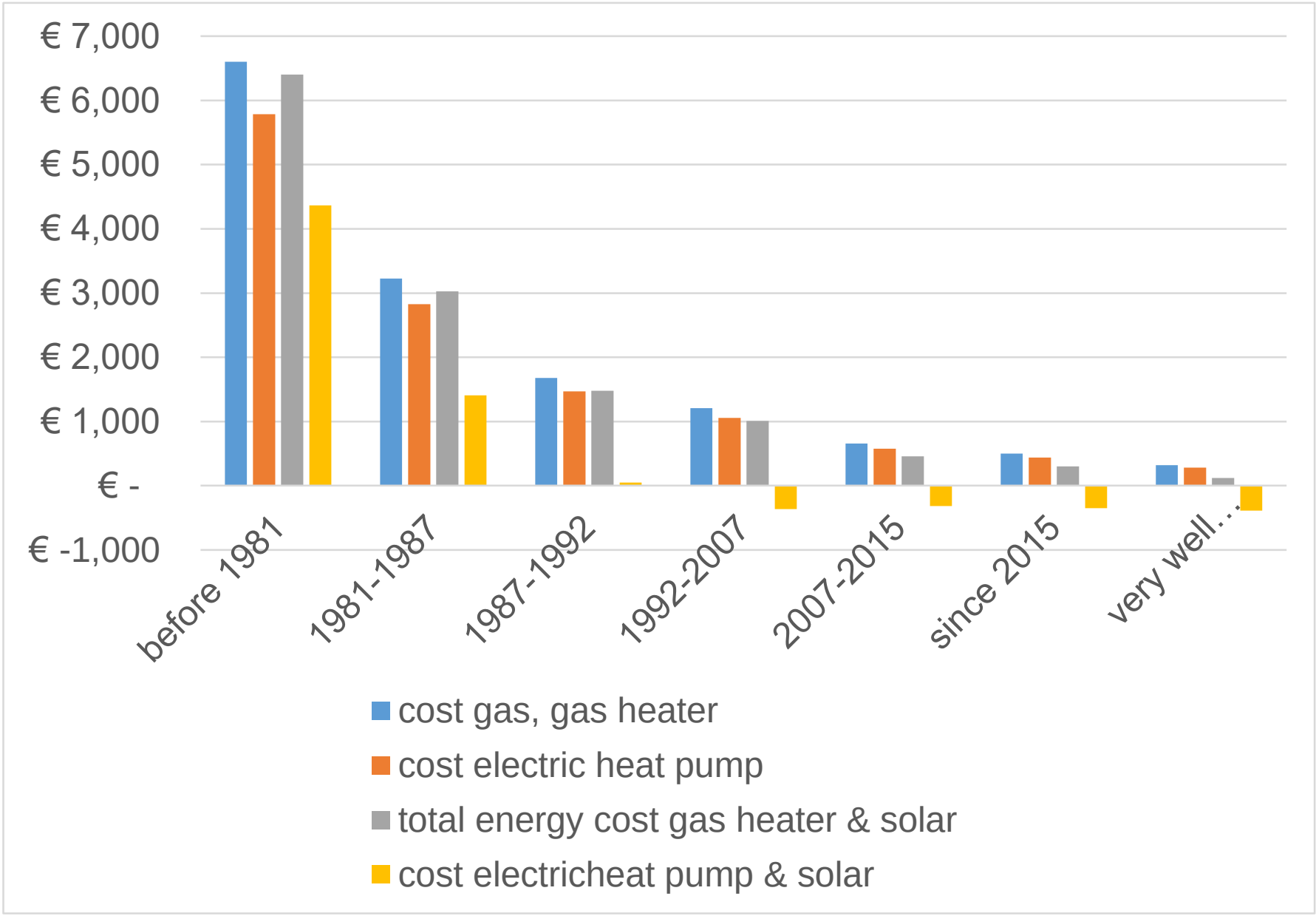


Transforming Heat Loss into Energy Labels and Cost

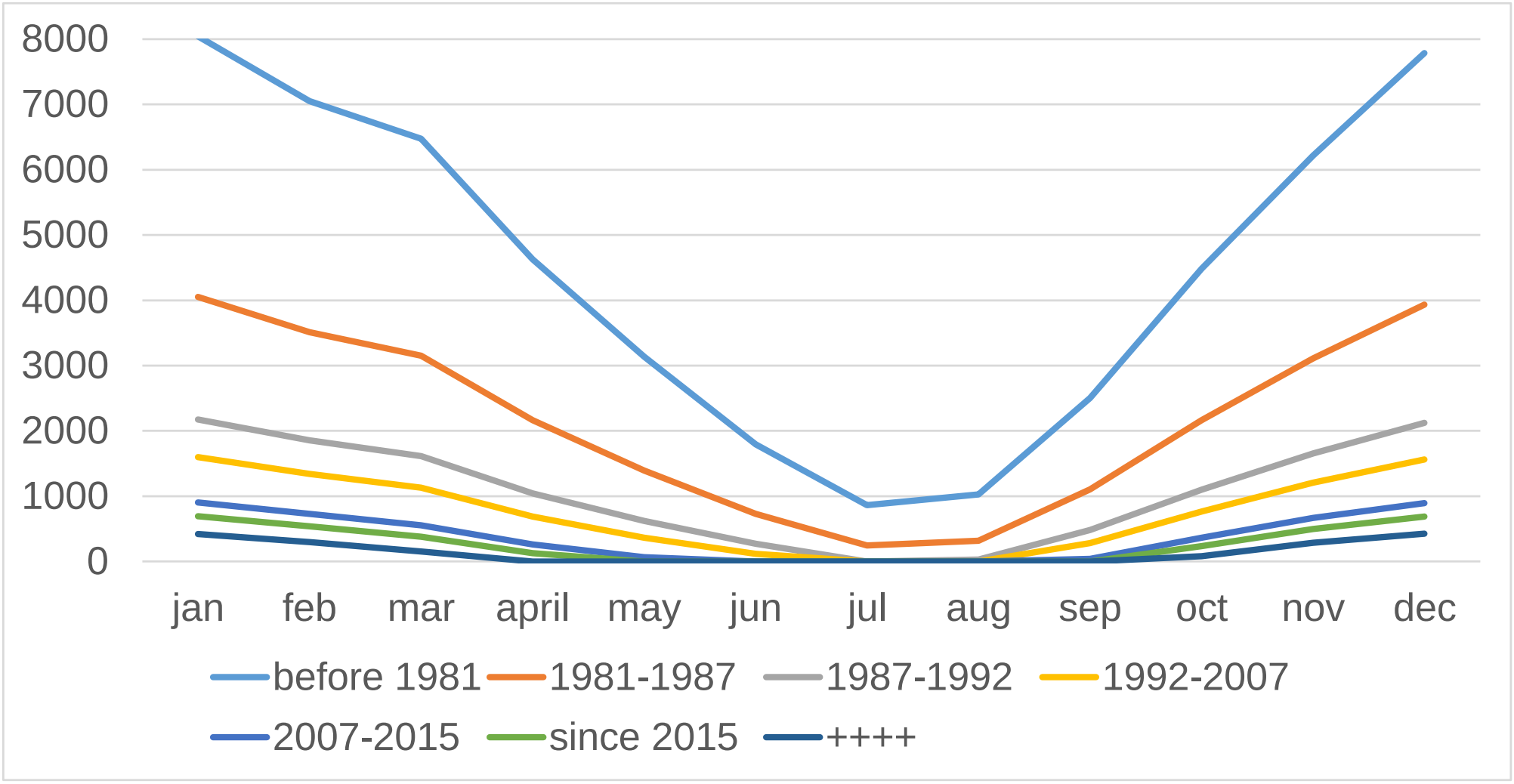
years	before 1981	1981-1987	1987-1992	1992-2007	2007-2015	since 2015	very well insulated
gas heater	G	C	A	A+	A+++	A+++	A+++
heat pump	B	A+	A+++	A+++	A+++	A+++	A+++
gas heater & solar	G	B	A++	A+++	A+++	A++++	A++++
heat pump & solar	A	A+++	A+++	A++++	A++++	A++++	A++++

years	before 1981	1981-1987	1987-1992	1992-2007	2007-2015	since 2015	very well insulated
cost gas, gas heater	€ 6,601	€ 3,225	€ 1,677	€ 1,207	€ 657	€ 499	€ 320
cost electric, heat pump	€ 5,786	€ 2,828	€ 1,470	€ 1,058	€ 576	€ 437	€ 280
total energy cost, gas heater & solar	€ 6,403	€ 3,027	€ 1,479	€ 1,009	€ 459	€ 301	€ 122
cost electric, heat pump & solar	€ 4,366	€ 1,407	€ 50	€ -362	€ -319	€ -350	€ -386

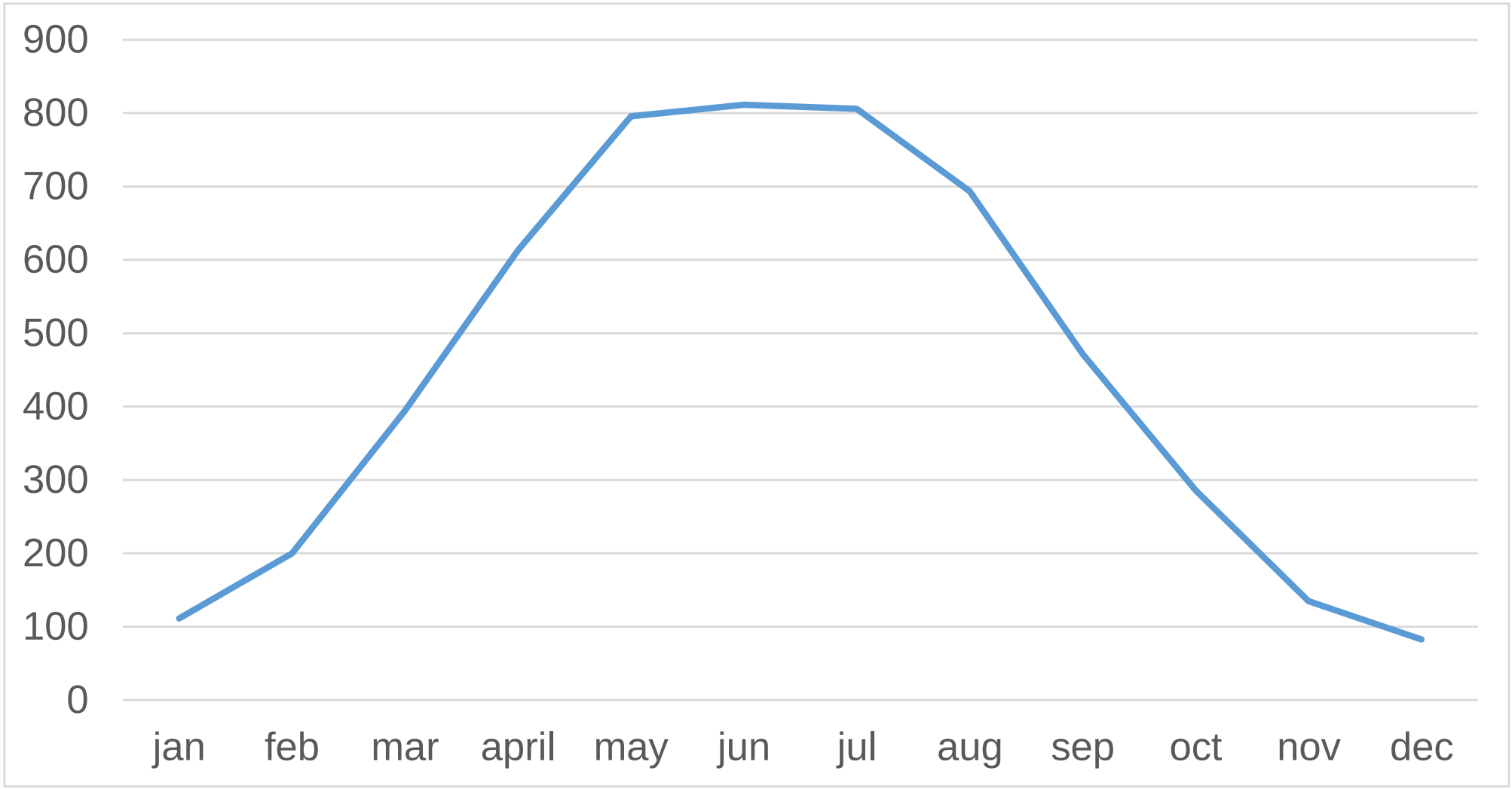
Energy Costs for Various Scenarios



Variation of Energy Consumption over the Year



Solar Production over a Year

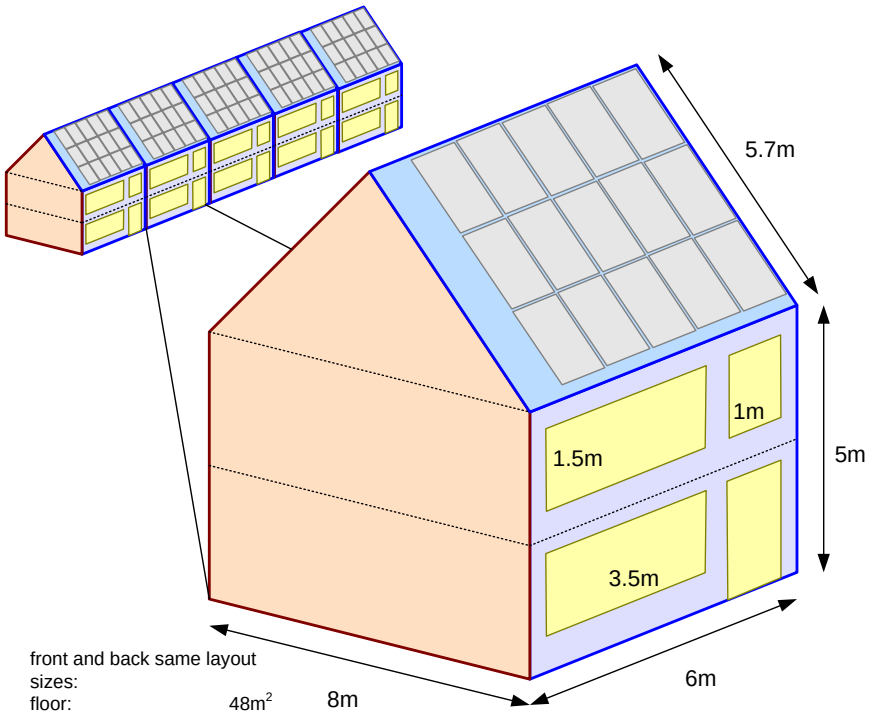


Best Duurzaam rowmhouse insulationl

Author: Gerrit Muller, contributions from many Best Duurzaam and working group strategy volunteers

BDRA3rowHouse Version 1.1, July 26, 2024

the standard row house



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https://glasherstelhermans.nl/isolatiewaarde-glas/

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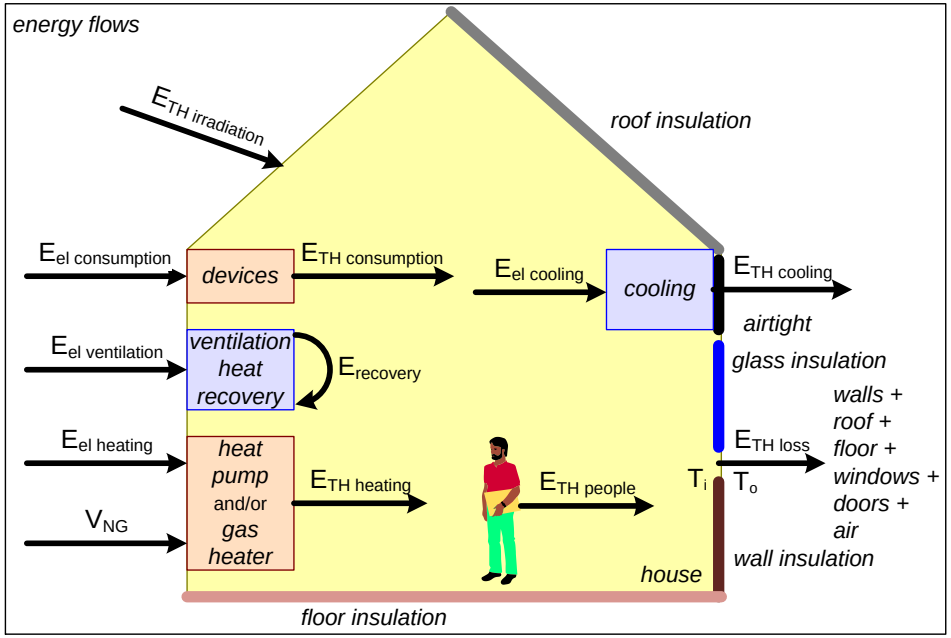

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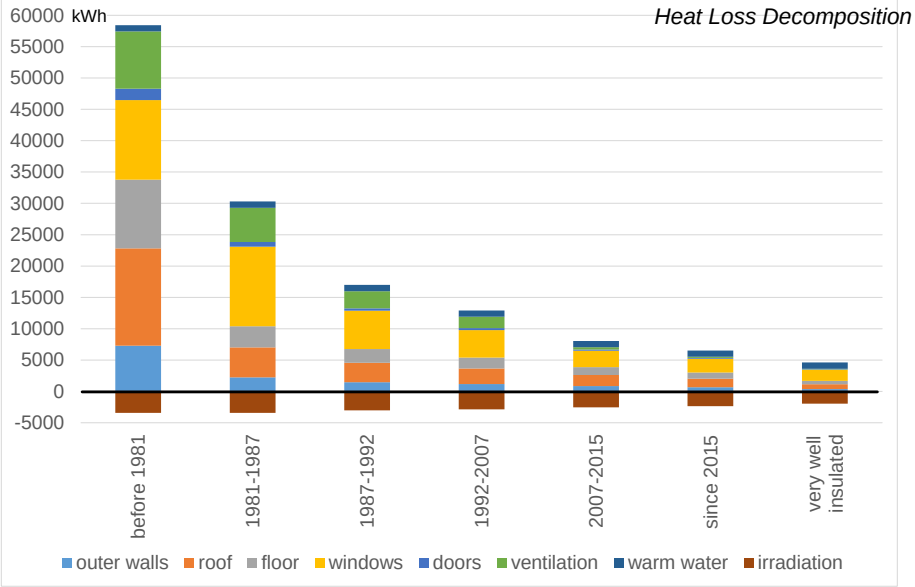

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increasing residential solar

increasing heat pumps

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