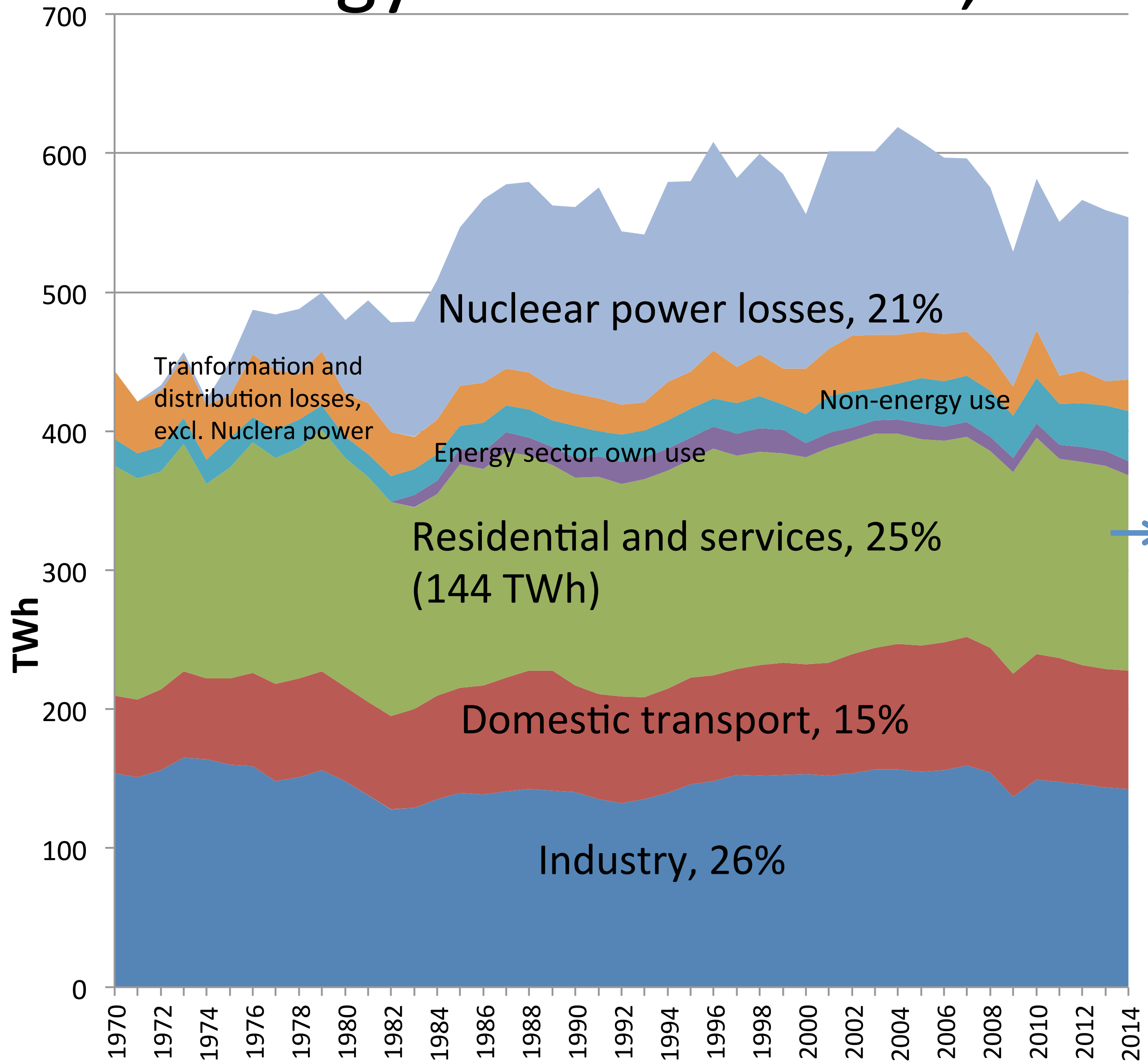
An optimum renovation strategy for Swedish single-family house envelopes: The implications of climate zones and the age of the houses

Farshid Bonakdar; Linnaeus University, Sweden
farshid.bonakdar@lnu.se

Angela Sasic Kalagasidis; Chalmers University of Technology, Sweden
angela.sasic@chalmers.se

Energy use in Sweden, 1970-2014

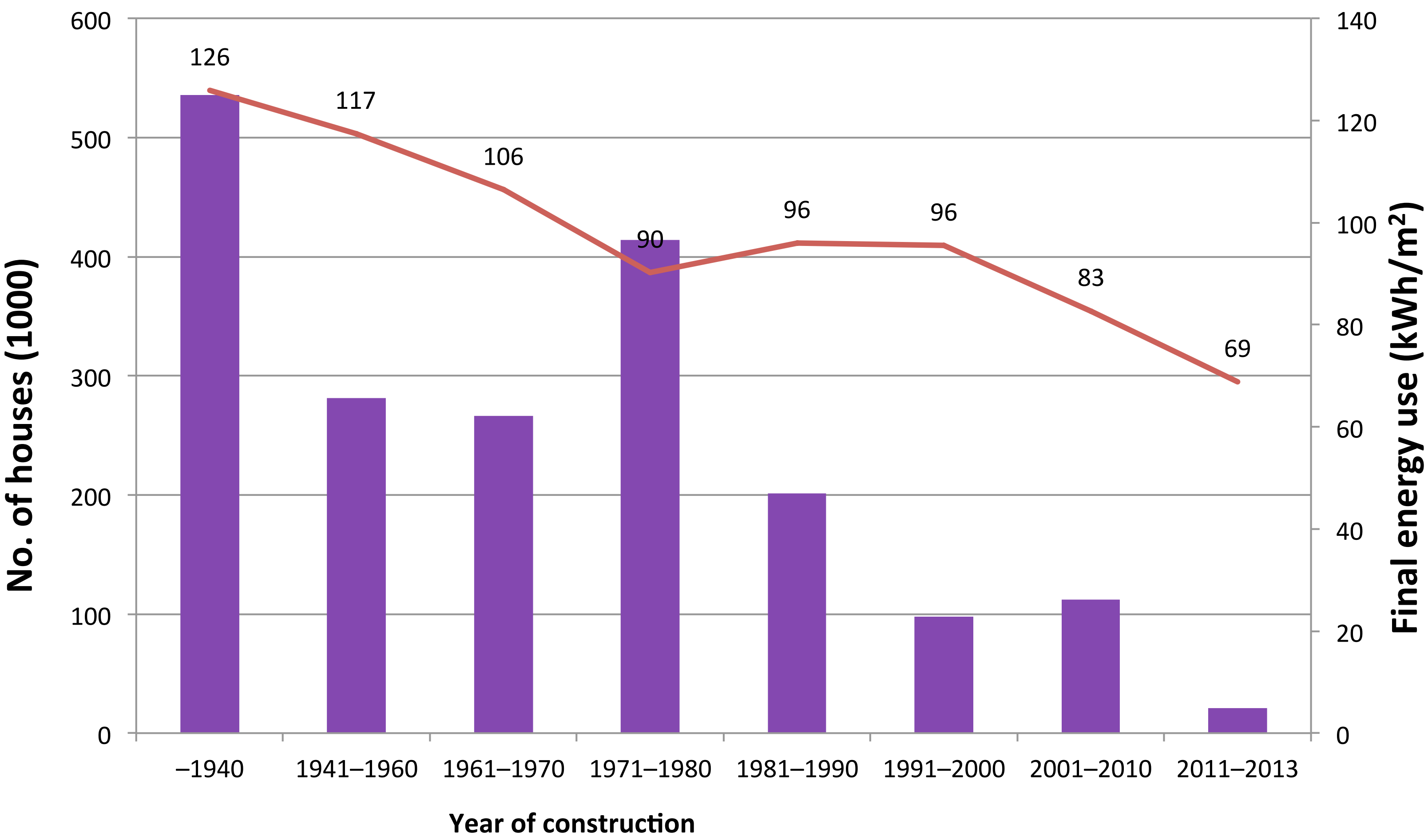


60% (or 76 TWh) used for space heating & hot water

of which

41% (or 31 TWh) in detached house

Swedish detached housing stock and final energy use, 2014



(Energistatistisk för småhus 2014)

Representative single-family houses

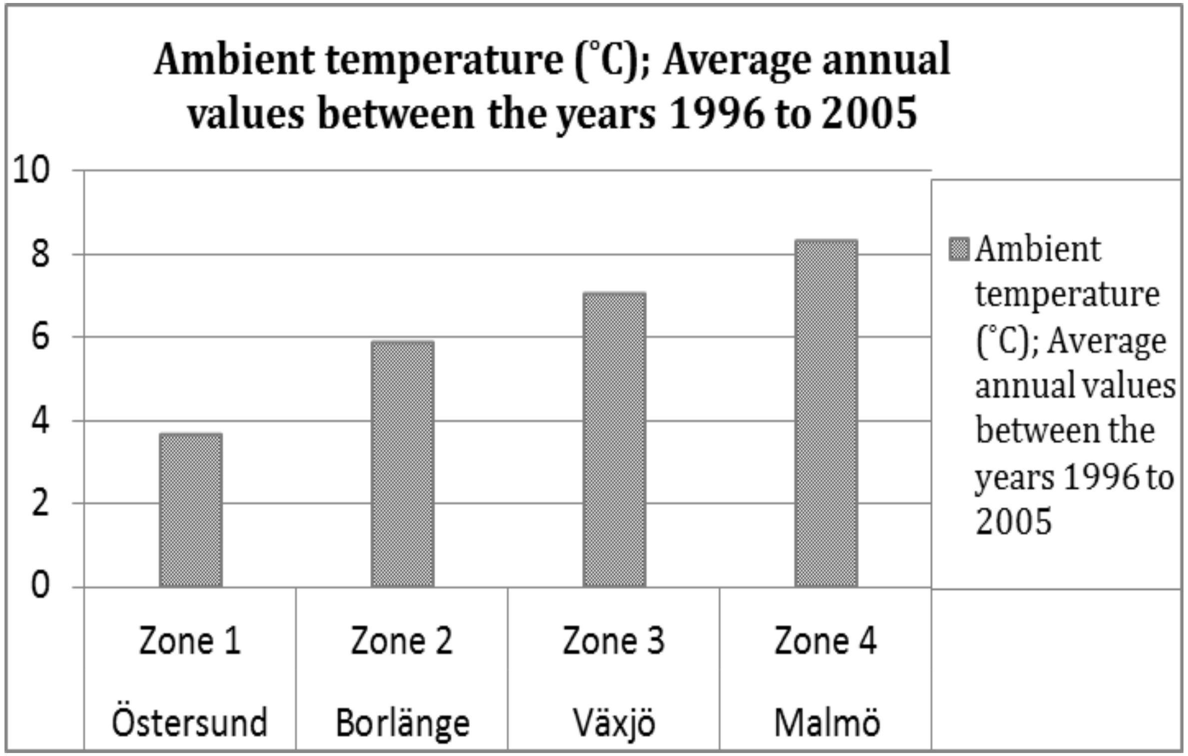
Building age group (Built during....)	Identified as:	Total number in Sweden*
1961 – 1975	Houses of 1970	500,000
1976 – 1985	Houses of 1980	313,000
1986 - 1995	Houses of 1990	154,000

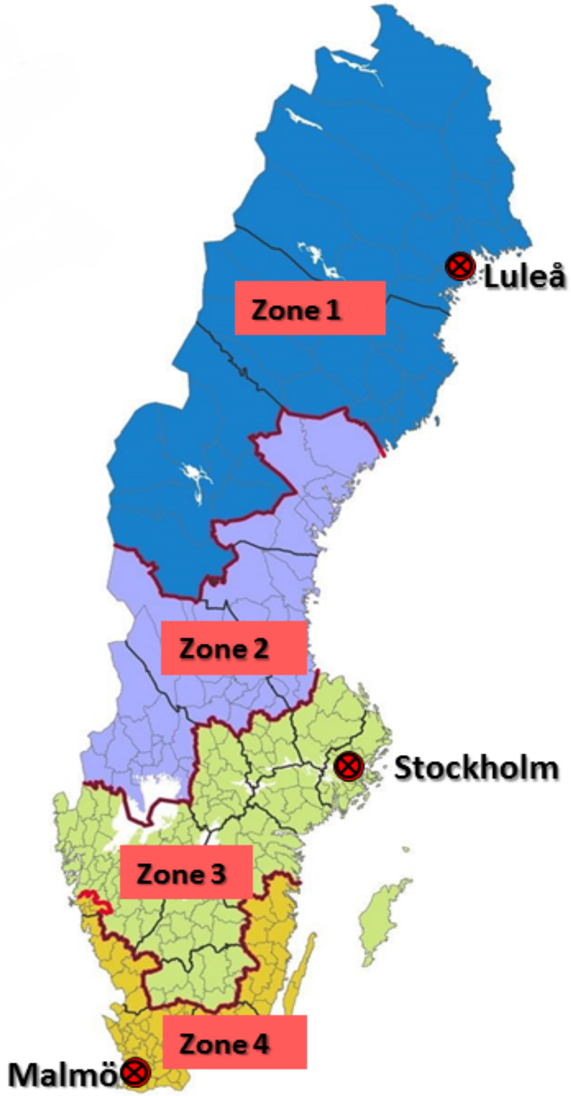
* According to BETSI survey, led by Swedish national board of housing, building and planning (Boverket)

Adopted from: *"Optimala kostnader för energyeffektivisering"* Boverket, 2013

House envelope component	Total area (m^2)	U-value ($W/m^2 K$)		
		Houses of 1970	Houses of 1980	Houses of 1990
Attic floor	75	0.21	0.15	0.12
Exterior walls	100	0.31	0.21	0.17
Windows	22	2.3	2.0	1.9

Four climate zones of Sweden





Adopted from: *"Ändring av Boverkets byggregler (BBR)"*, Boverket, 2015

Energy balance simulation of the houses: VIP-Energy simulation package

Estimated space heat demand (kWh/m^2/year)

Houses from	Zone 1	Zone 2	Zone 3	Zone 4
1970	181.3	158.1	143.8	127.6
1980	157.6	136.9	124.3	109.9
1990	147.8	128.3	116.4	102.7

Optimum-level and cost-effectiveness of energy renovation

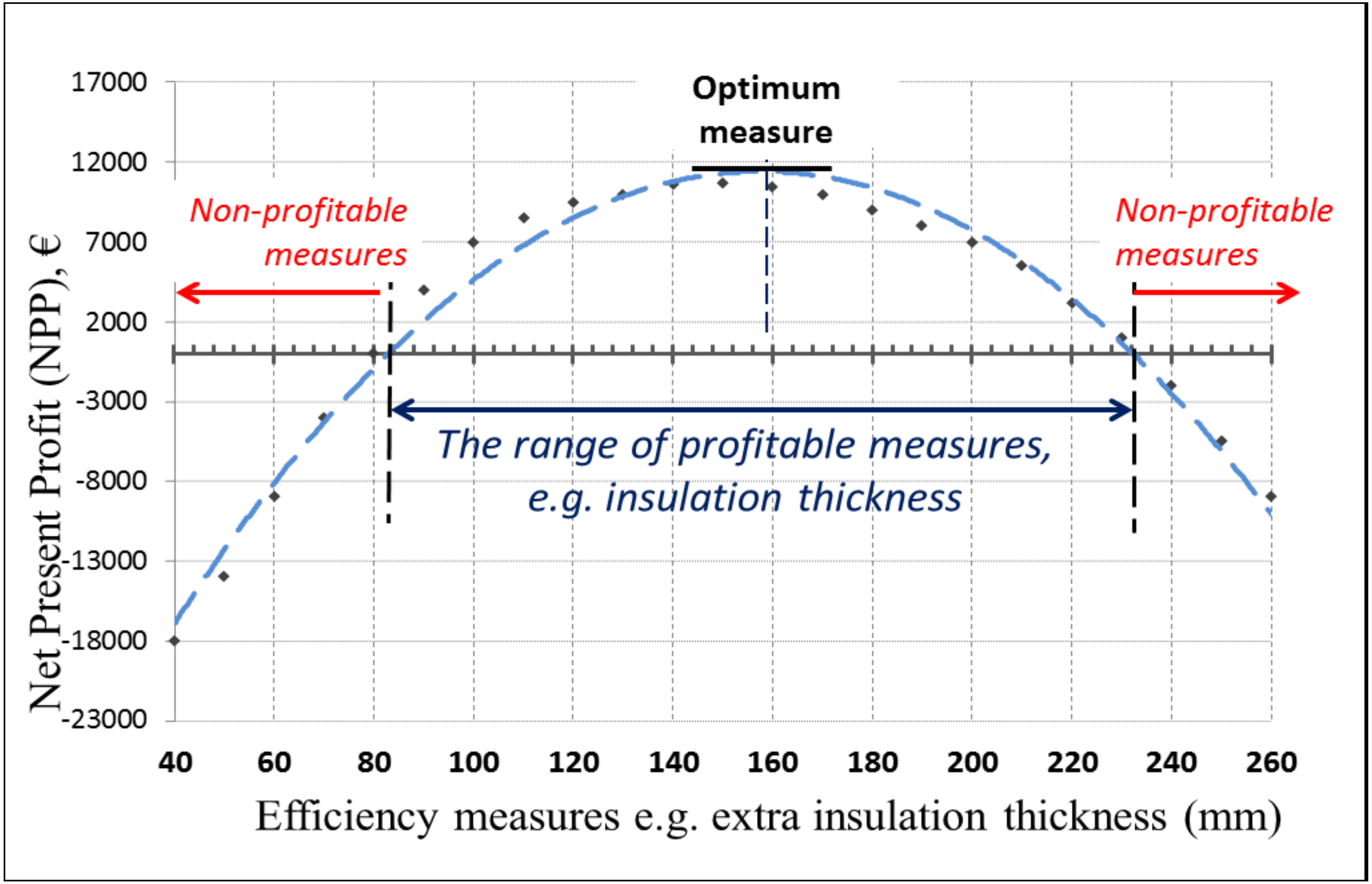
$$\text{Net Present Profit (NPP)} = \sum_{t=1}^{n} C_t/(1+R)^t - INV$$

C_t = net cash inflow (saved energy cost) during the building lifespan after renovation **(n)**;

INV = total initial investment for energy renovation;

R = real discount rate.

Net Present Profit



Energy efficiency measures for house envelope renovation

Additional insulation (mineral wool blanket) on attic floor:

Thicknesses (mm) $\in \{50, \ldots.\ldots, 500\}$

Additional insulation (mineral wool panel) on exterior walls:

Thicknesses (mm) $\in \{45, \ldots.\ldots, 500\}$

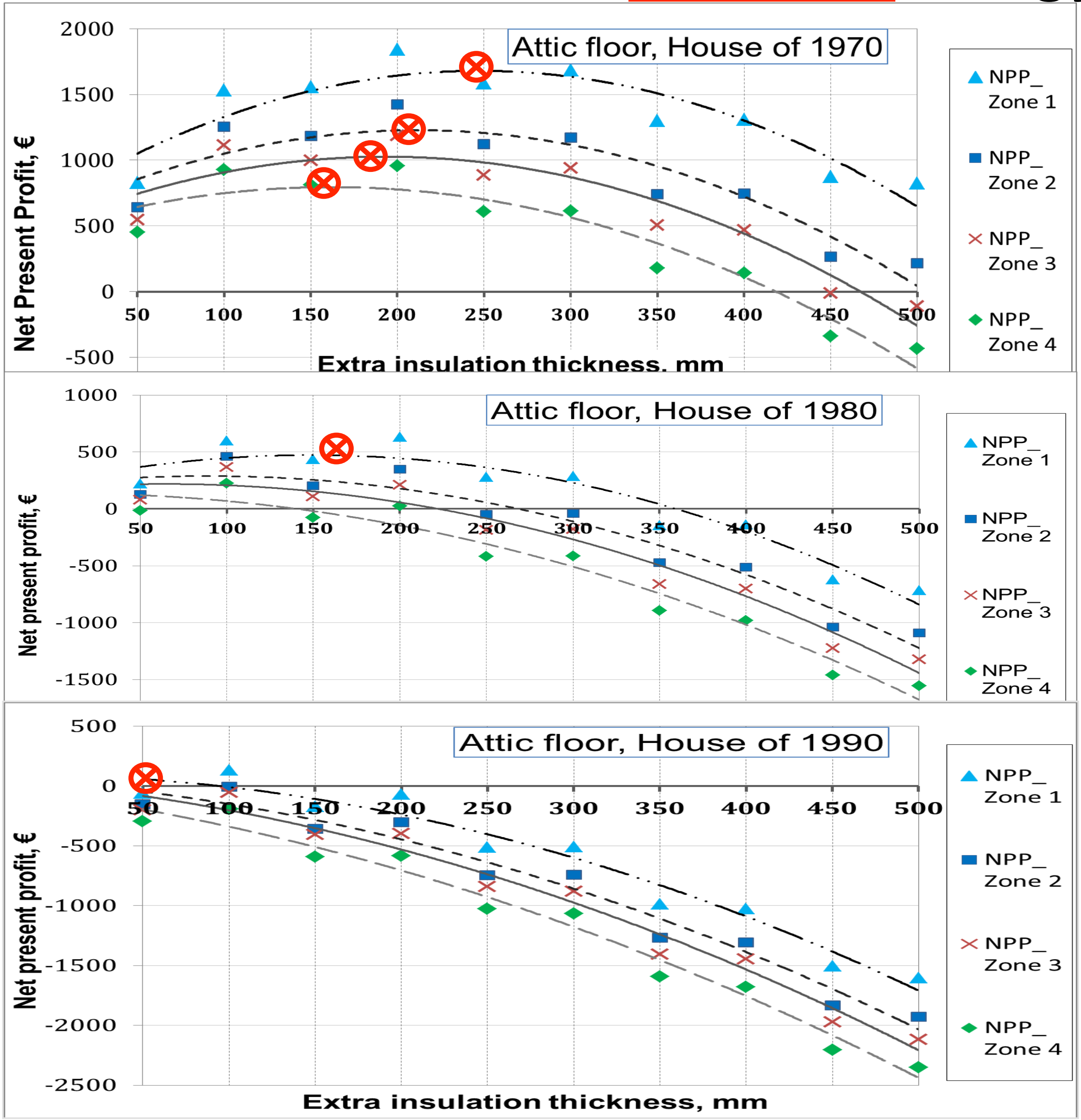
Windows:

New windows U-value (W/m^{2}K) $\in \{1.2, \ldots\ldots., 0.6\}$

Assumptions

- Lifespan of the energy efficiency measures (i.e. additional insulation and new windows) = 50 years
- Discount rate of 3%
- DH price increase of 1.5%
- Renovation cost: calculated based on Swedish construction work tariff (Wikells)
- The renovation is for energy conservation purpose only (meaning, there is no need for repair or maintenance)

NPP calculation for Attic floor energy renovation



What to notice:

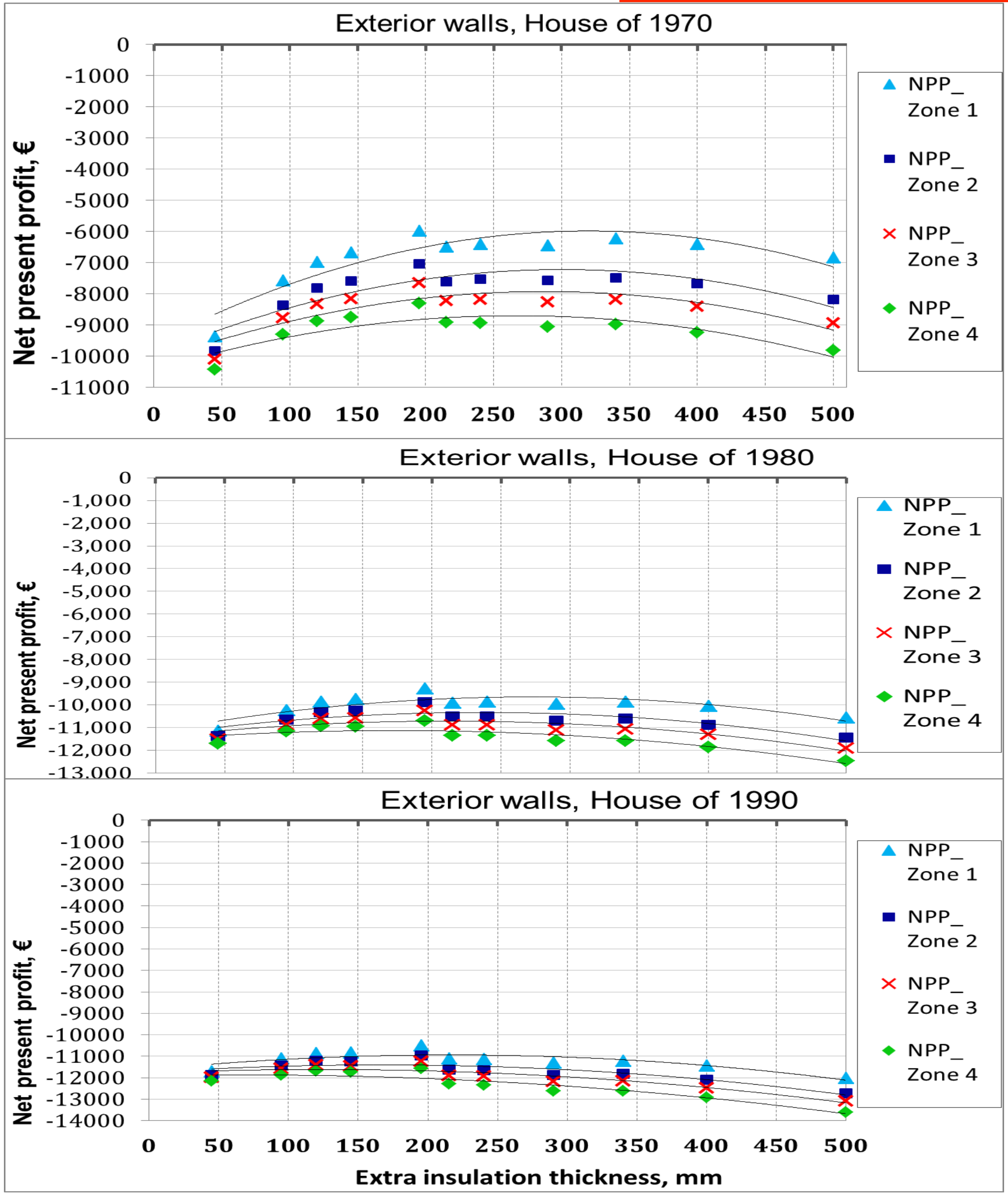
The reduction trend of NPP and optimum thickness when:

1) Climate Zone changes from Zone 1 to Zone 4;

2) The age of the houses varies from 1970s to 1990s

And: Majority of cases are cost-effective

NPP calculation for exterior walls energy renovation



What to notice:

The reduction trend of NPP when:

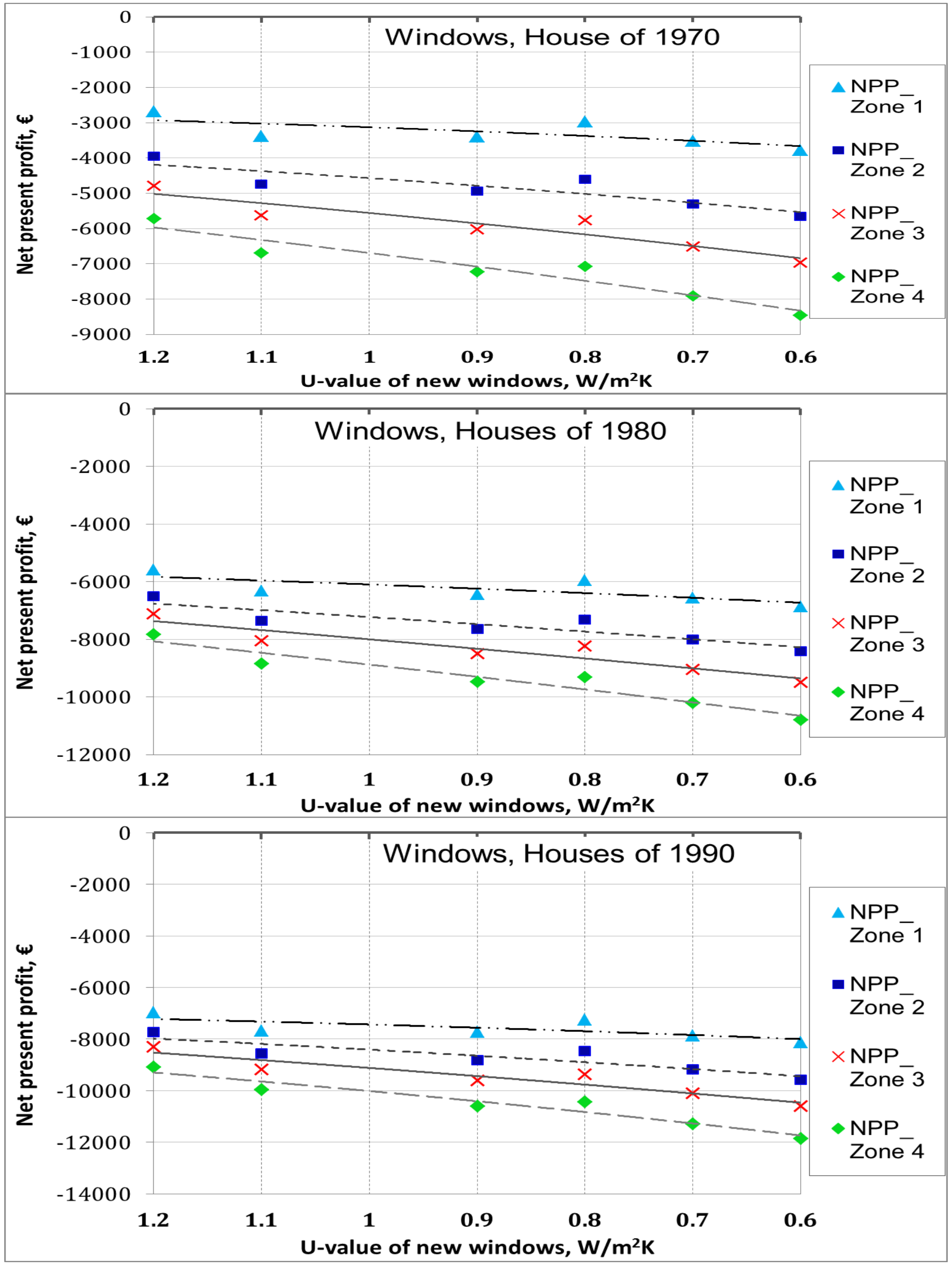
1) Climate Zone changes from 1 to 4;

2) The age of the houses varies from 1970s to 1990s;

And:

None is cost-effective (assuming no need of façade repair and improvement)

NPP calculation for windows energy renovation



What to notice:

The reduction trend of NPP when:

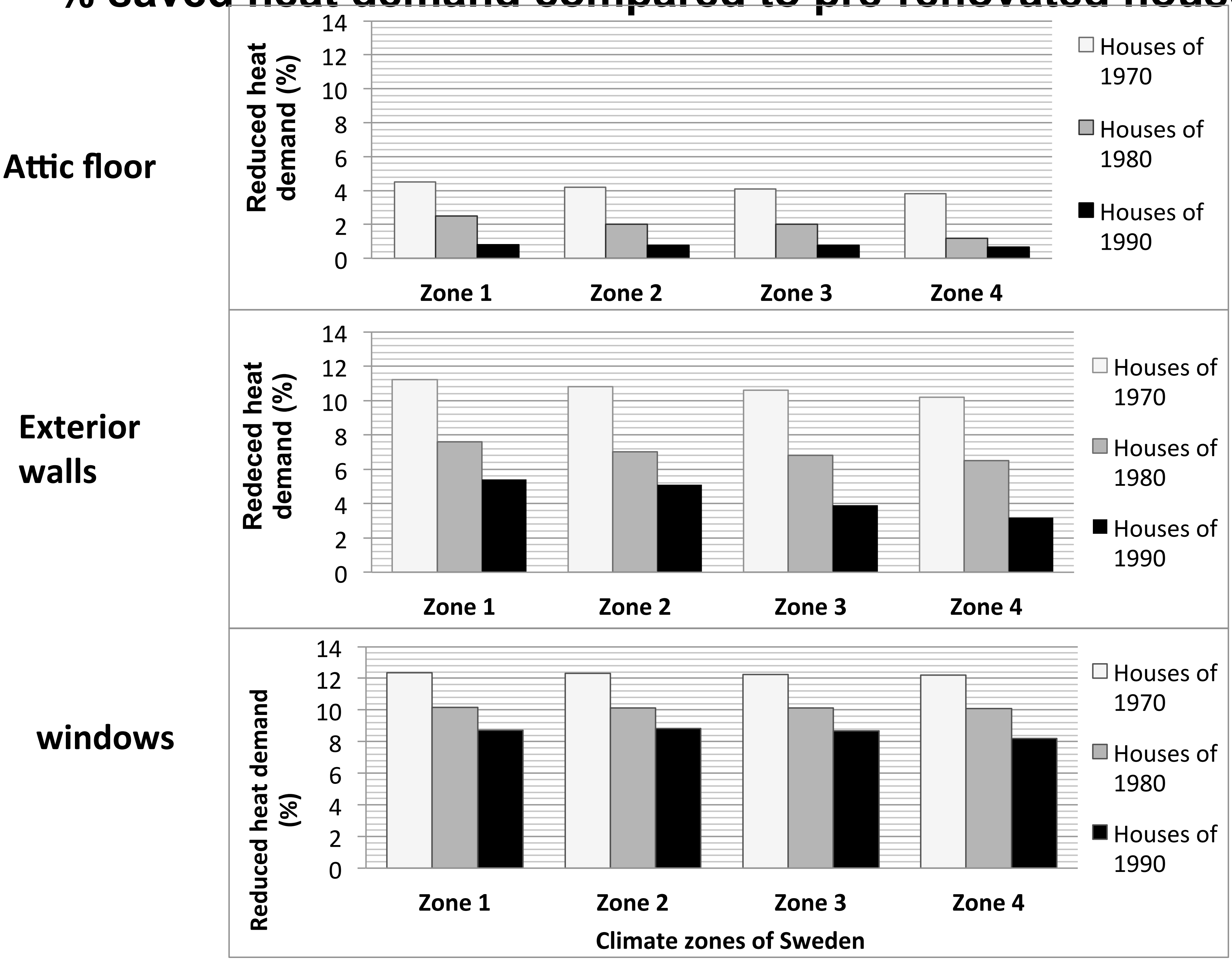
1) Climate Zone changes from 1 to 4;

2) The age of the houses varies from 1970s to 1990s;

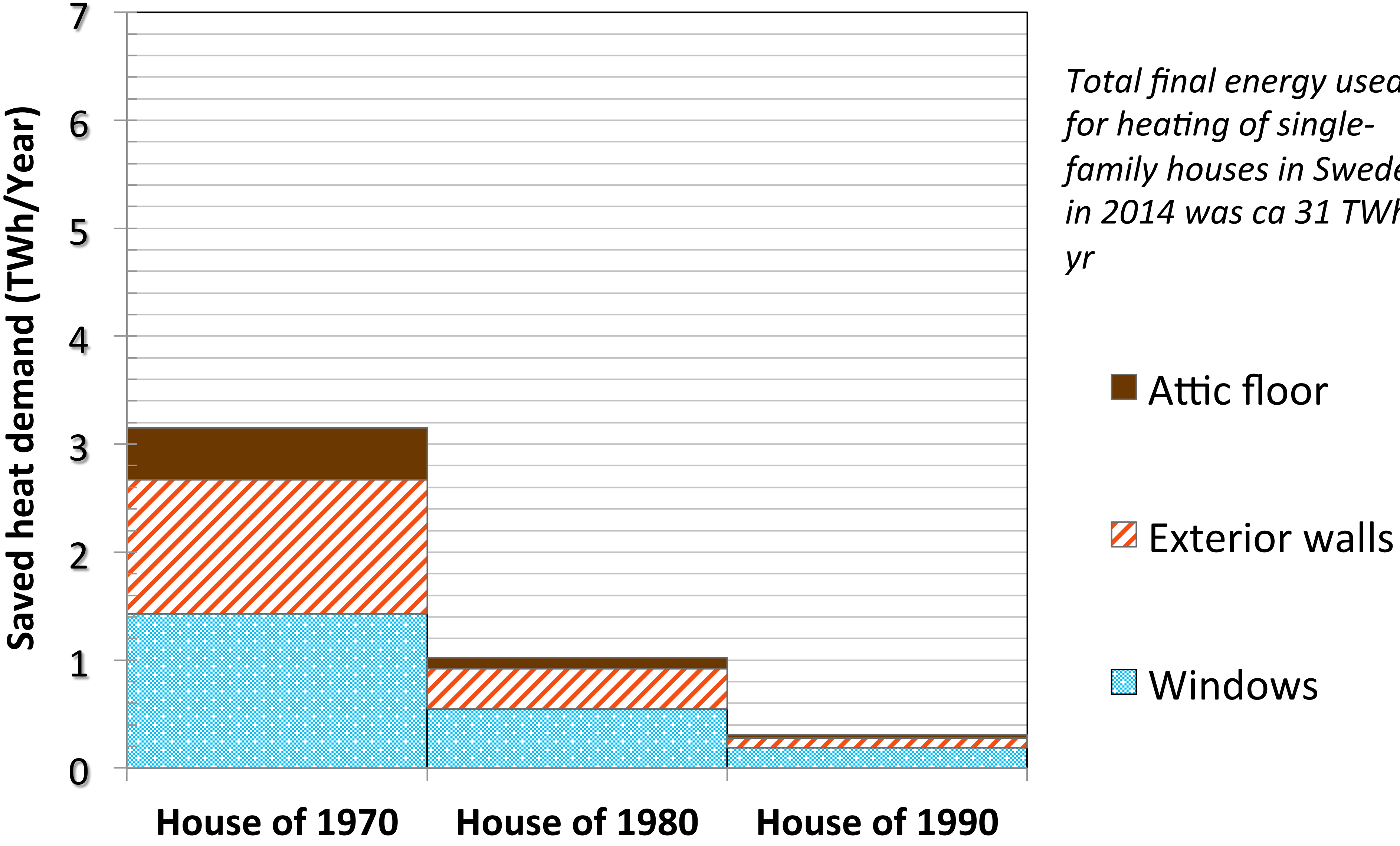
And:

None is cost-effective (assuming the windows are not in need of any renovation)

% saved heat demand compared to pre-renovated house

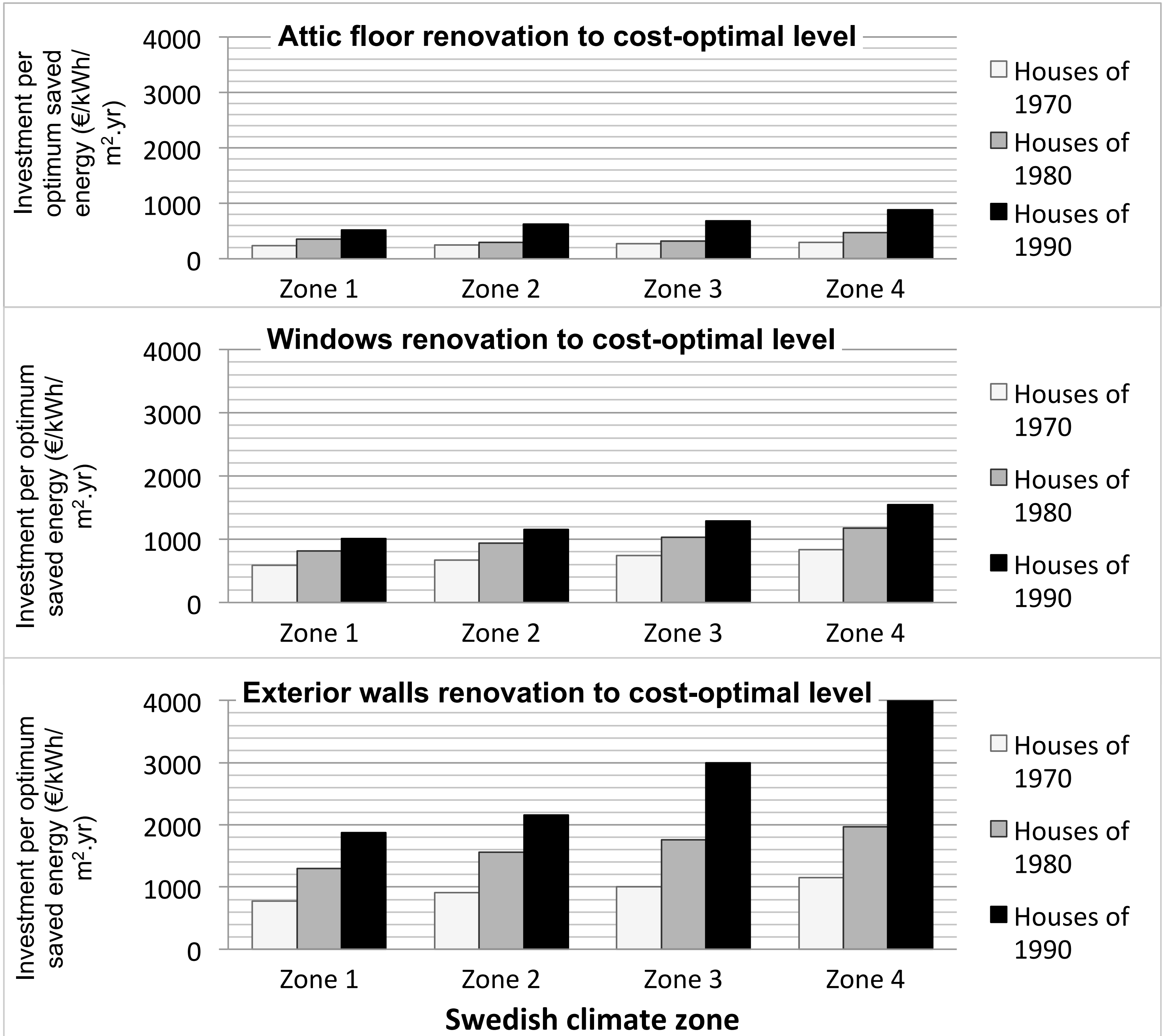


Linear accumulated saved heat demand for each house group due to optimal level of renovation of components



Total final energy used for heating of single-family houses in Sweden in 2014 was ca 31 TWh/yr

Investment cost per reduced heat demand (€/kWh per m²)



Main findings

The existing single-family houses in Sweden have significant potential for reducing final energy use, if the following priority is taken into account

1- Initiate the renovation, to an optimal level, from Climate Zone 1, followed by Zones 2, 3 and 4;

2- Start renovating the houses of 1970, followed by 1980 and 1990;

3- Start the house envelope renovation, to an optimal level, from Attic floor, followed by windows and exterior walls.

Thank you!