Design strategies to minimise heating and cooling demands for passive houses under changing climate

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Aim

- To analyse implications of future climate scenarios on energy use and overheating risk of a passive house building
- To assess different design strategies to minimise energy use and overheating risk of the house under future climate scenarios

Introduction

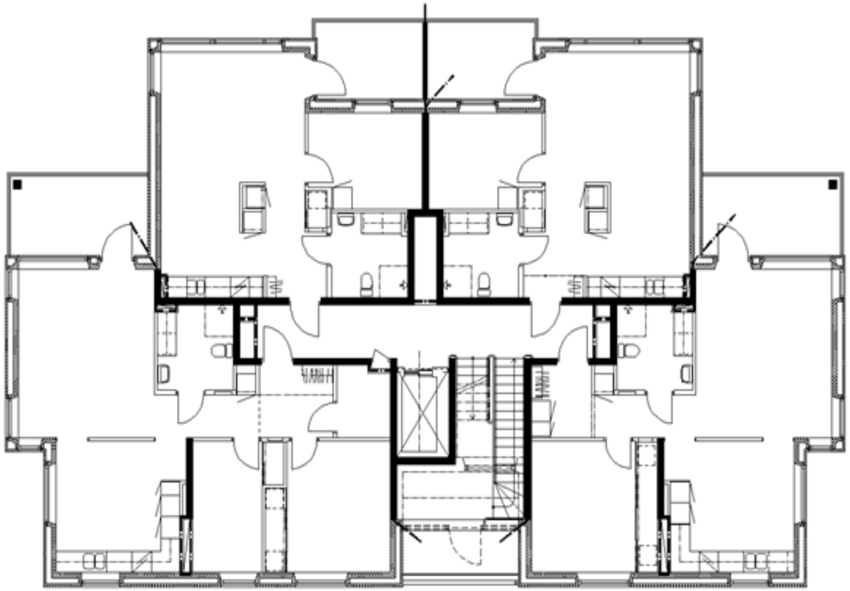
- Average temperature for Europe between 2002–2011 is 1.3°C higher than that for 1850-1899
- Average temperature in Sweden predicted to rise by 2-6 °C in 2100 compared to 1961-1990 levels
- Climate change may influence energy use and indoor environment profiles of buildings

Studied building

(a)

Photograph

(b)

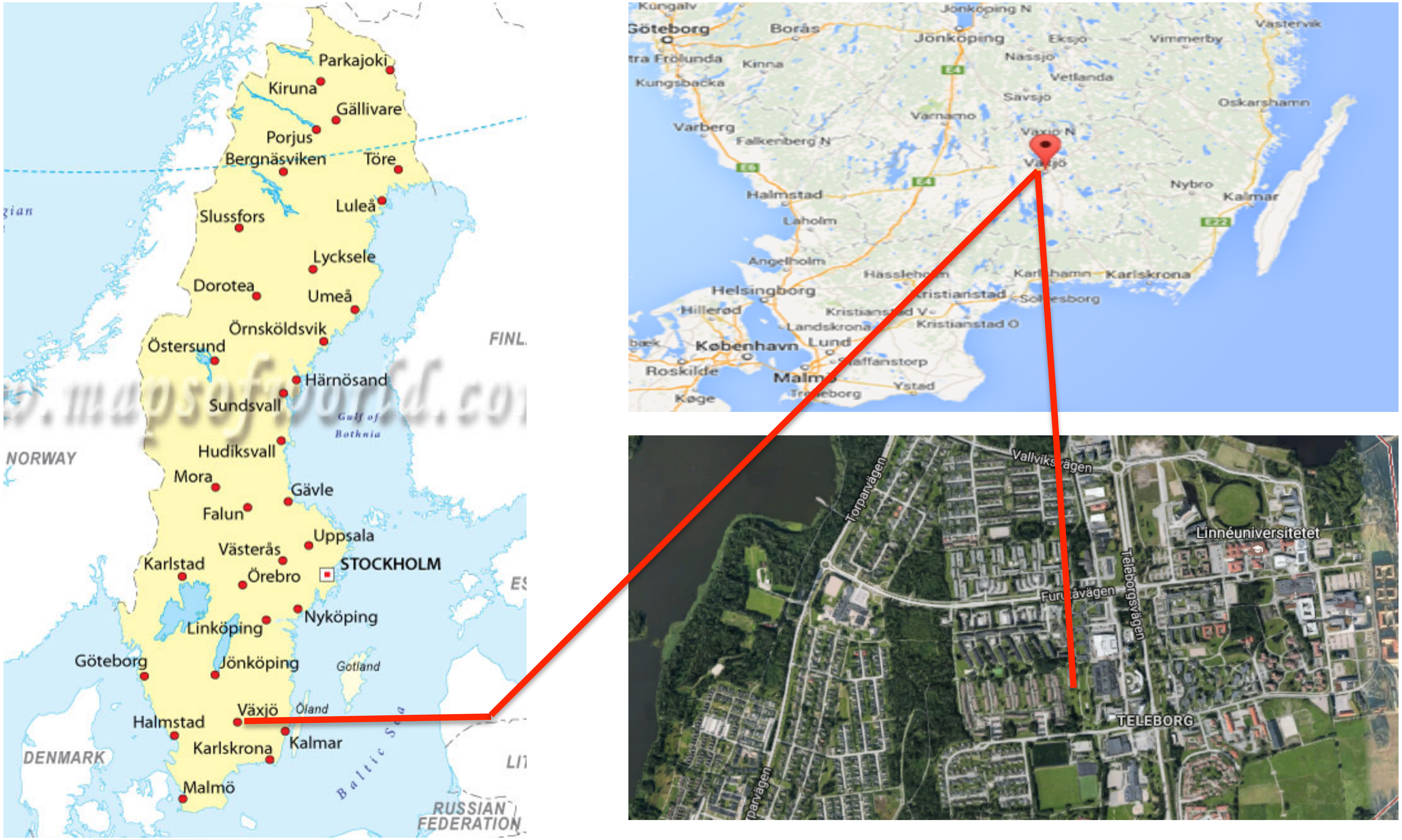


Typical floor plan

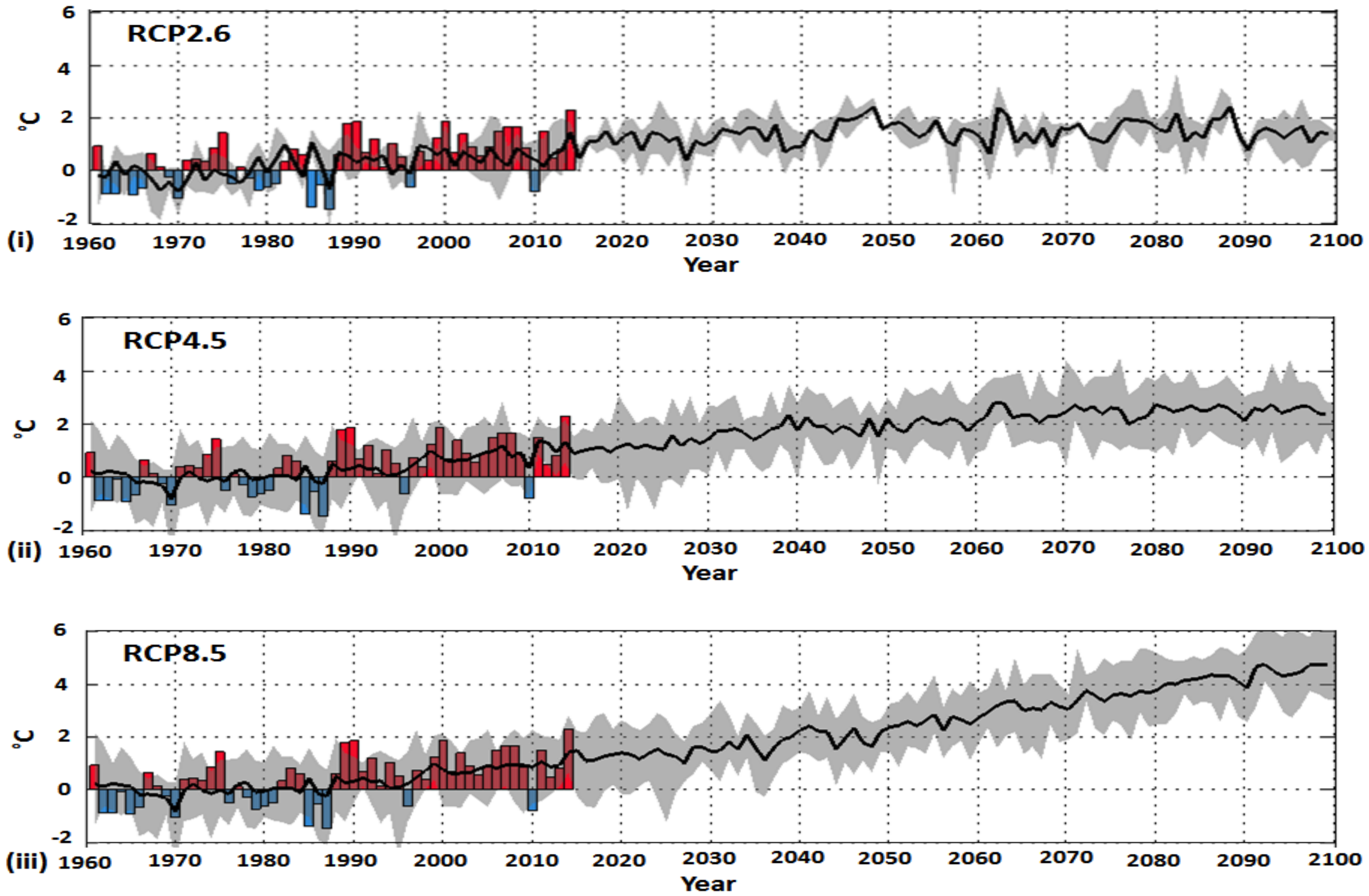
- Built in 2014 in Växjö
- Concrete frame
- 6 storeys
- 24 apartments
- 1686 m^2 living area
- Redesigned to meet Passiv house criteria

Building	**U-value (W/m^{2}K)**					**Air-leakage at 50 Pa (l /s m^2)**	**Mechanical ventilation**
	Ground floor	**External walls**	**Windows**	**Doors**	**Roof**		
Passivhouse	0.11	0.11	0.80	0.80	0.05	0.3	Balanced with (76%) heat recovery

Studied building location



Annual mean temperature variations for Kronoberg county, Sweden



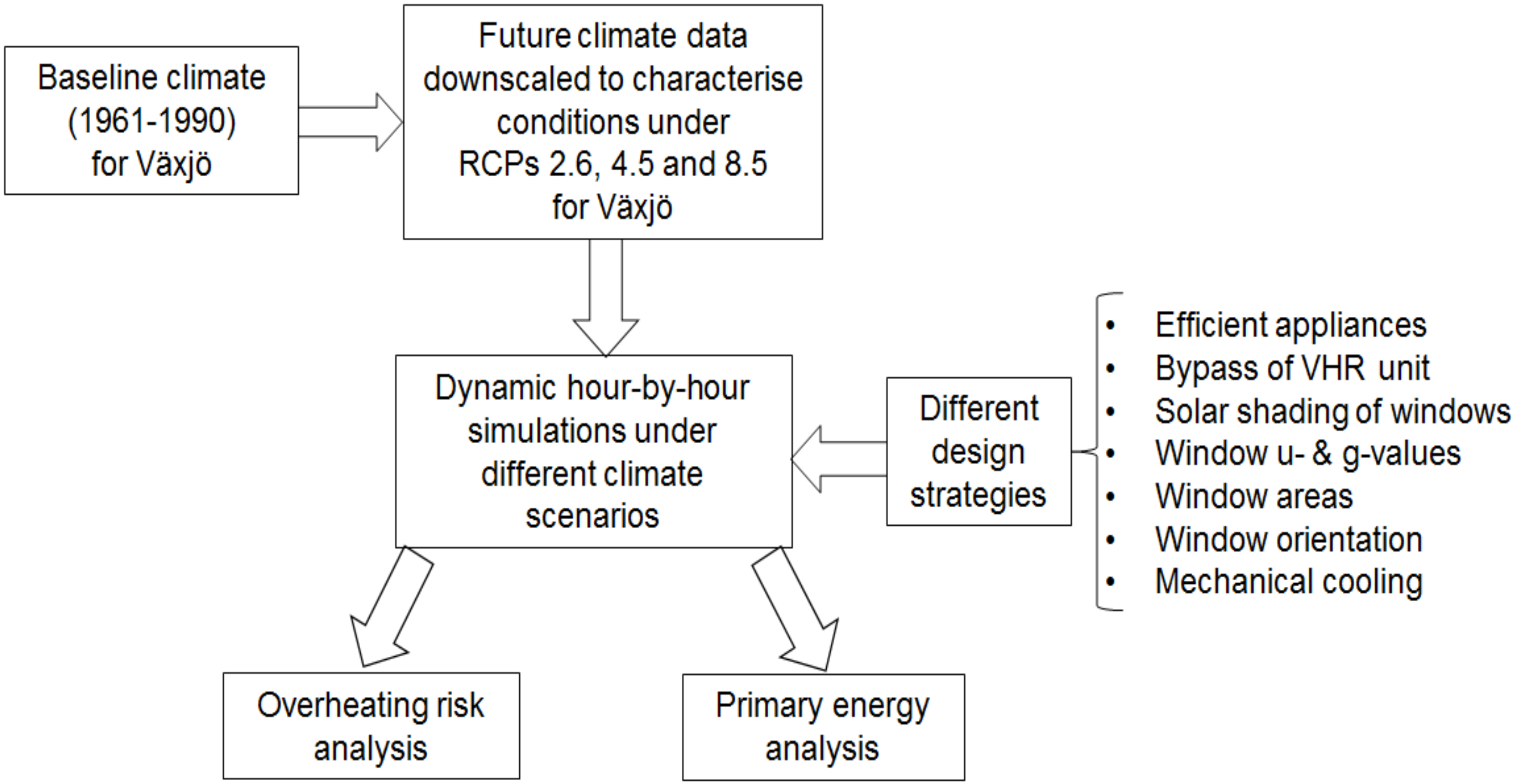
RCP2.6 (i), RCP4.5 (ii) and RCP8.5 (iii), relative to 1961-1990

Adapted from Swedish Meteorological and Hydrological Institute, Klimatscenarier (Climate Scenarios).
Available at http://www.smhi.se/klimat/framtidens-klimat/klimatscenarier#area=swe&dnr=99&sc=rcp85&seas=ar&var=t. 2013.

Design strategies

- Efficient household equipment and technical installations based on best available technology (BAT)
- By-passing the ventilation heat recovery (VHR) unit when the cooling set point is exceeded.
- Solar shading of windows to be activated when the cooling set point is exceeded.
- Different combinations of window thermal (u-values) and solar (g-values) transmittances.
- Decreasing or increasing the proportion of window areas on different façades by 20 and 40%.
- Different façades orientations to optimise space heating and cooling demand.
- Mechanical cooling with air conditioners when cooling set point is exceeded.

Methodological approach



Considered renewable energy supply technologies

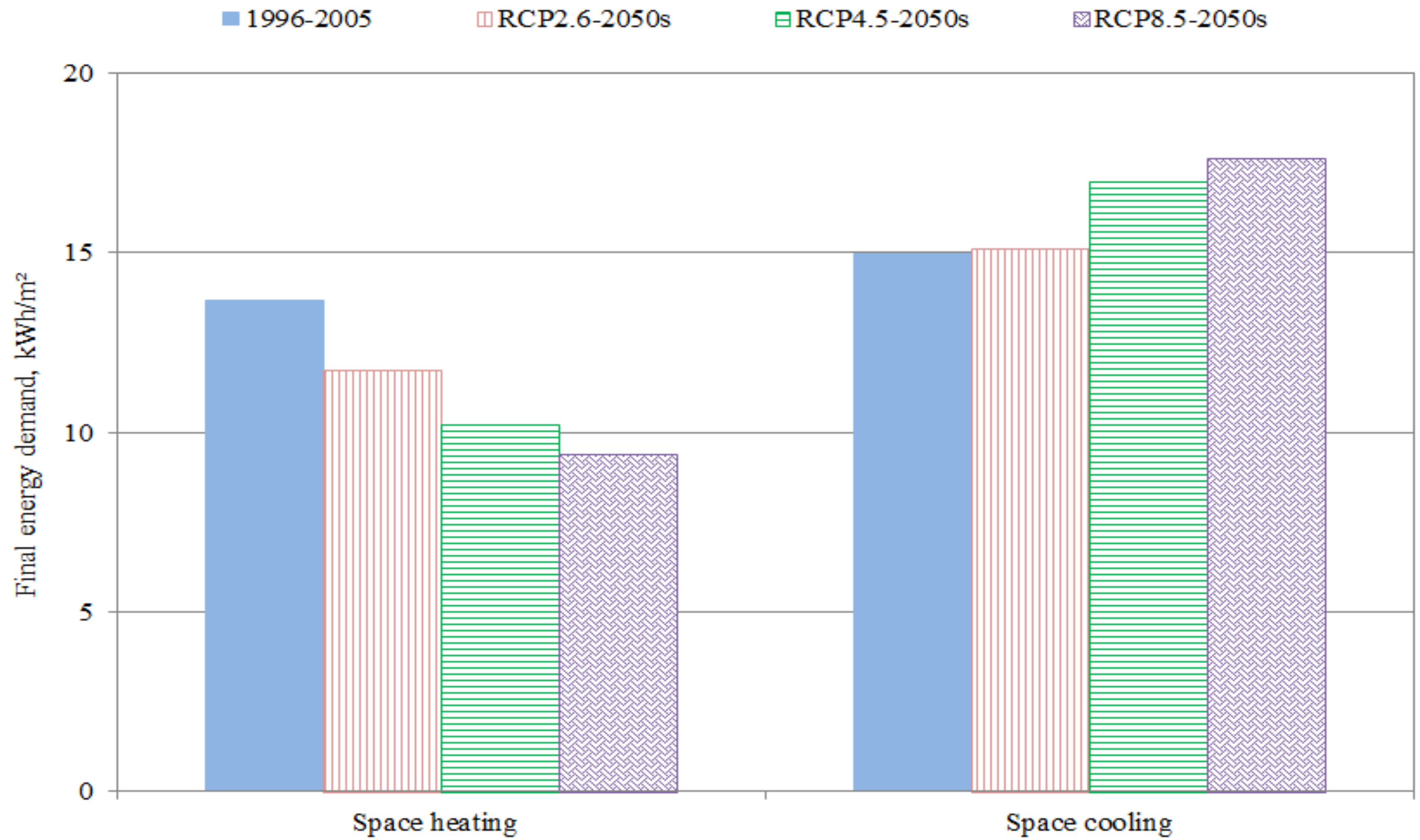
Technology	Capacity	Efficiency
Stand-alone power plant:	*(MW_{elec})*	*(η_{elec})*
Biomass steam turbine (BST)	400	0.40
Cogeneration plants:	*(MW_{heat})*	*(η_{elec}/η_{heat})*
CHP-BST	81	0.29/0.78
Heat-only boilers:	*(MW_{heat})*	*(η_{heat})*
Wood powder	50	0.88
Wood chip	50	1.08
End-use heating and cooling:		*(η)*
District heating heat exchanger		0.95
Room air conditioners		3

* Based on Truong N.L., Dodoo A., & Gustavsson L. (2014). Effects of heat and electricity saving measures in district-heated multistory residential buildings. Applied Energy, 118, 57-67.

Annual final energy demand and primary energy use under the reference climate (1996-2005)

Description	Annual final energy demand (kWh/m²)	Annual primary energy use (kWh/m²)
Space heating	13.6	8.7
Space cooling	14.9	13.6
Tap water heating	21	13.4
Ventilation electricity	5.2	14.2
Household electricity	31.6	86.1
Total	86.4	136.1

Space heating and cooling demands of the building under different climate scenarios



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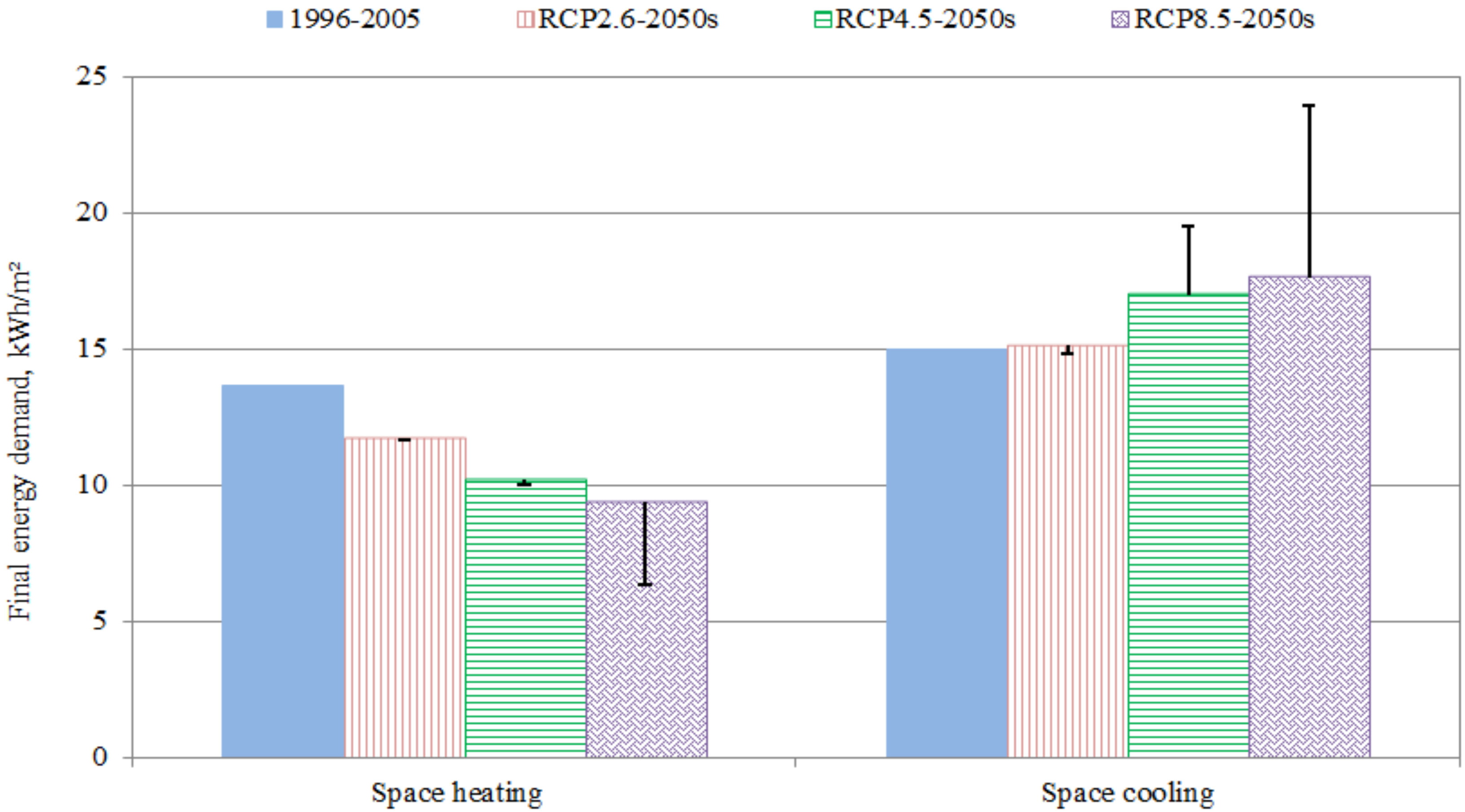
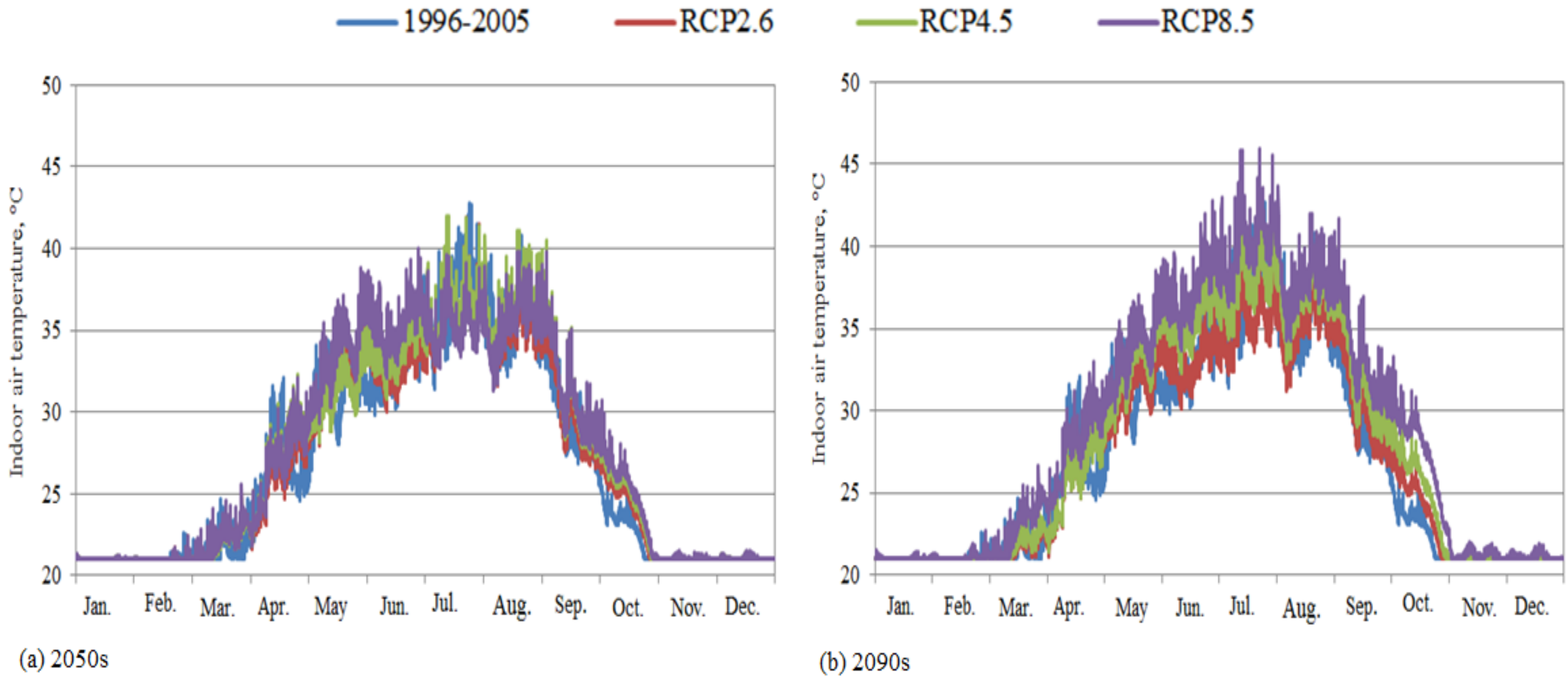
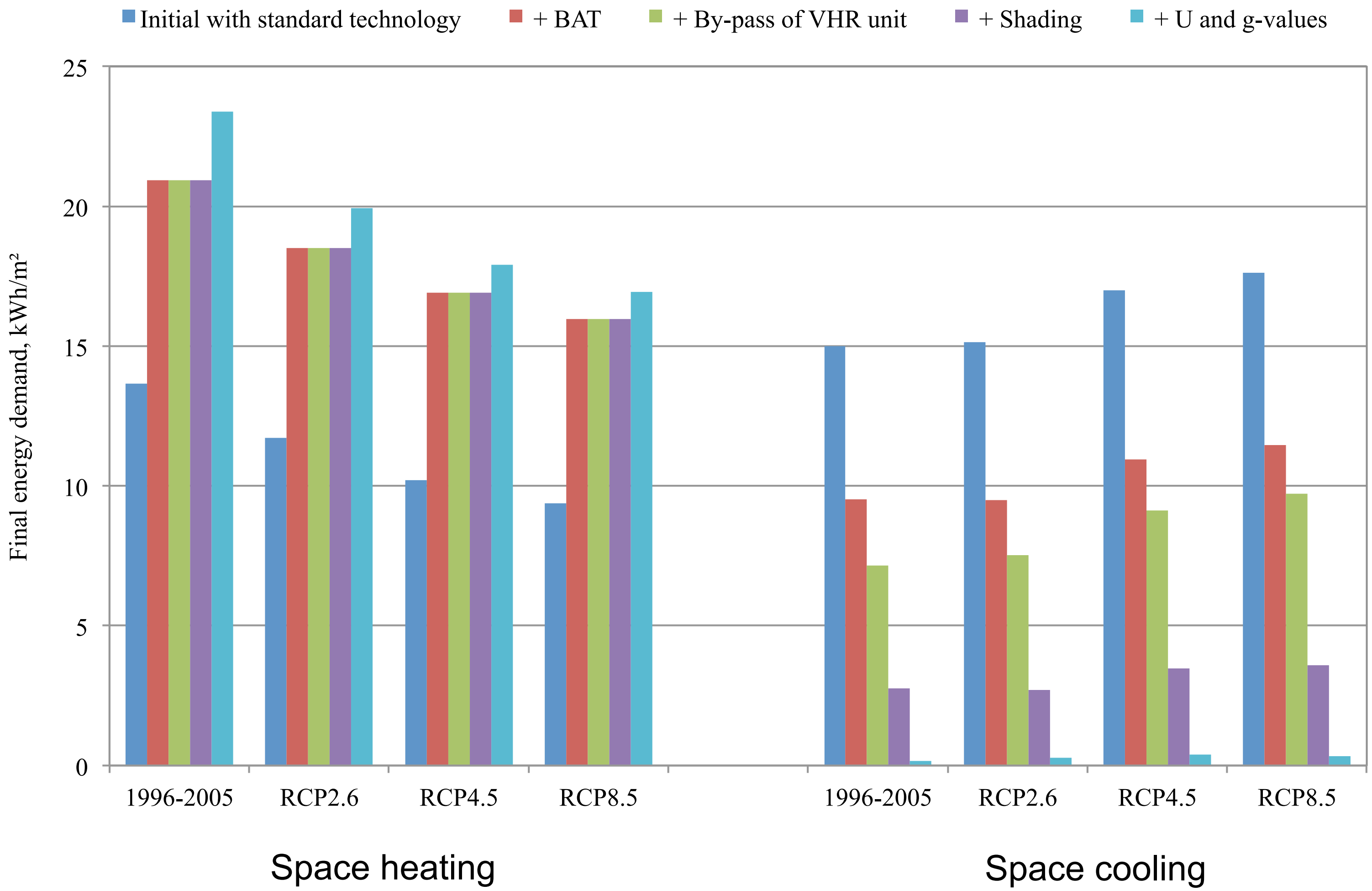


Main bars show mid-century (2050s), while error bars show end of century (2090s) climate scenarios

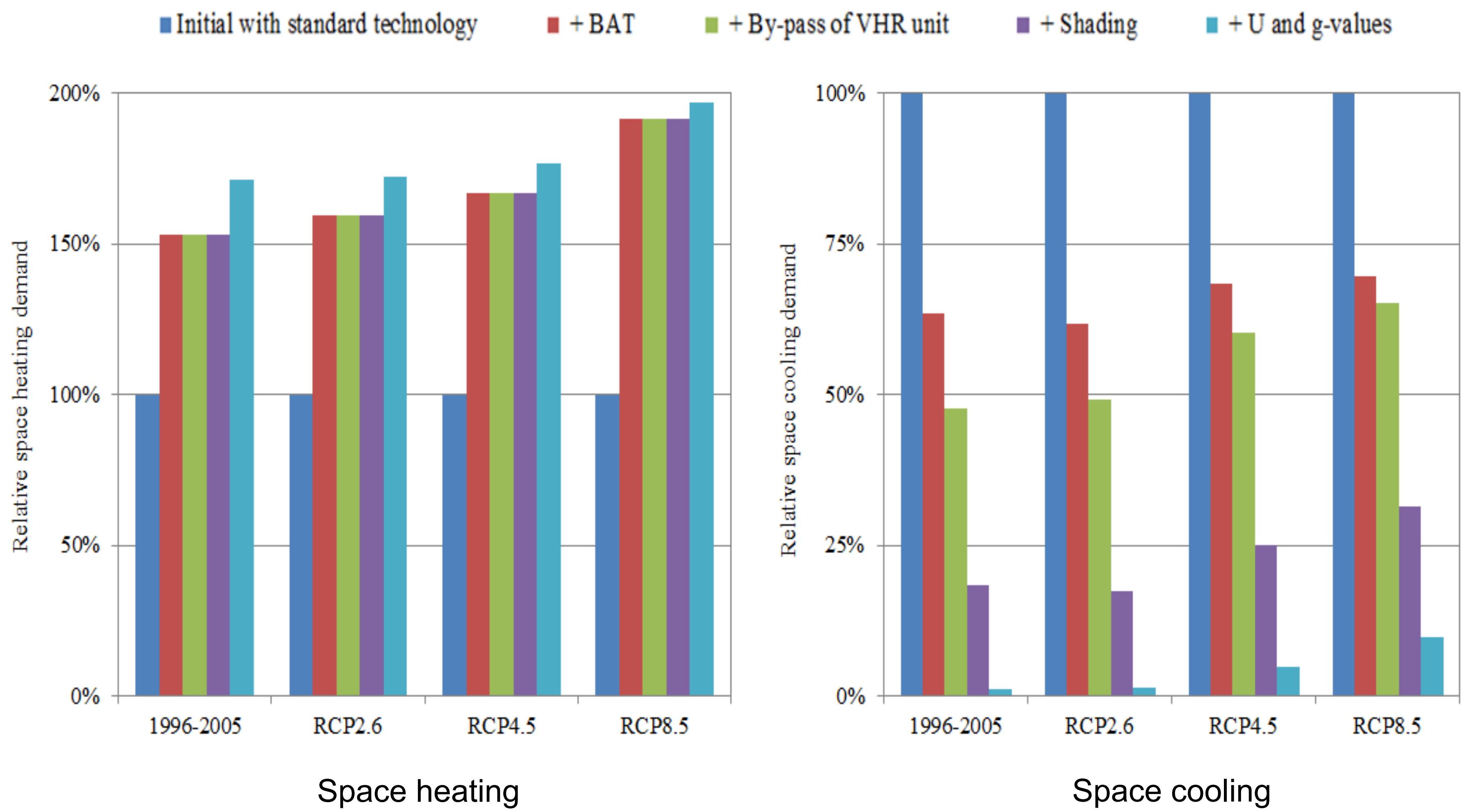
Annual hourly indoor air temperature profile for the building under different climate scenarios



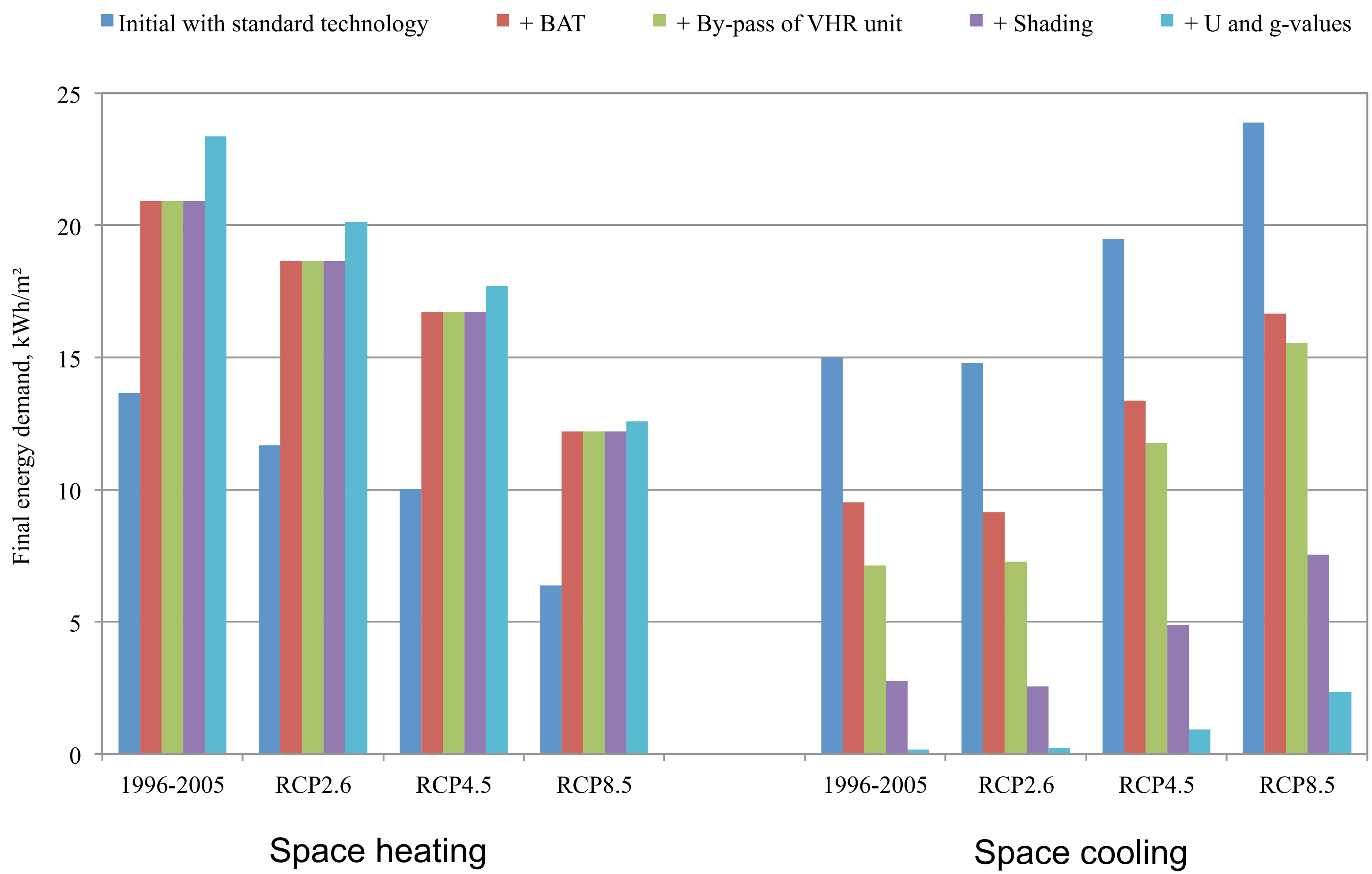
Space heating and cooling demand with different strategies under 2050s climate scenarios



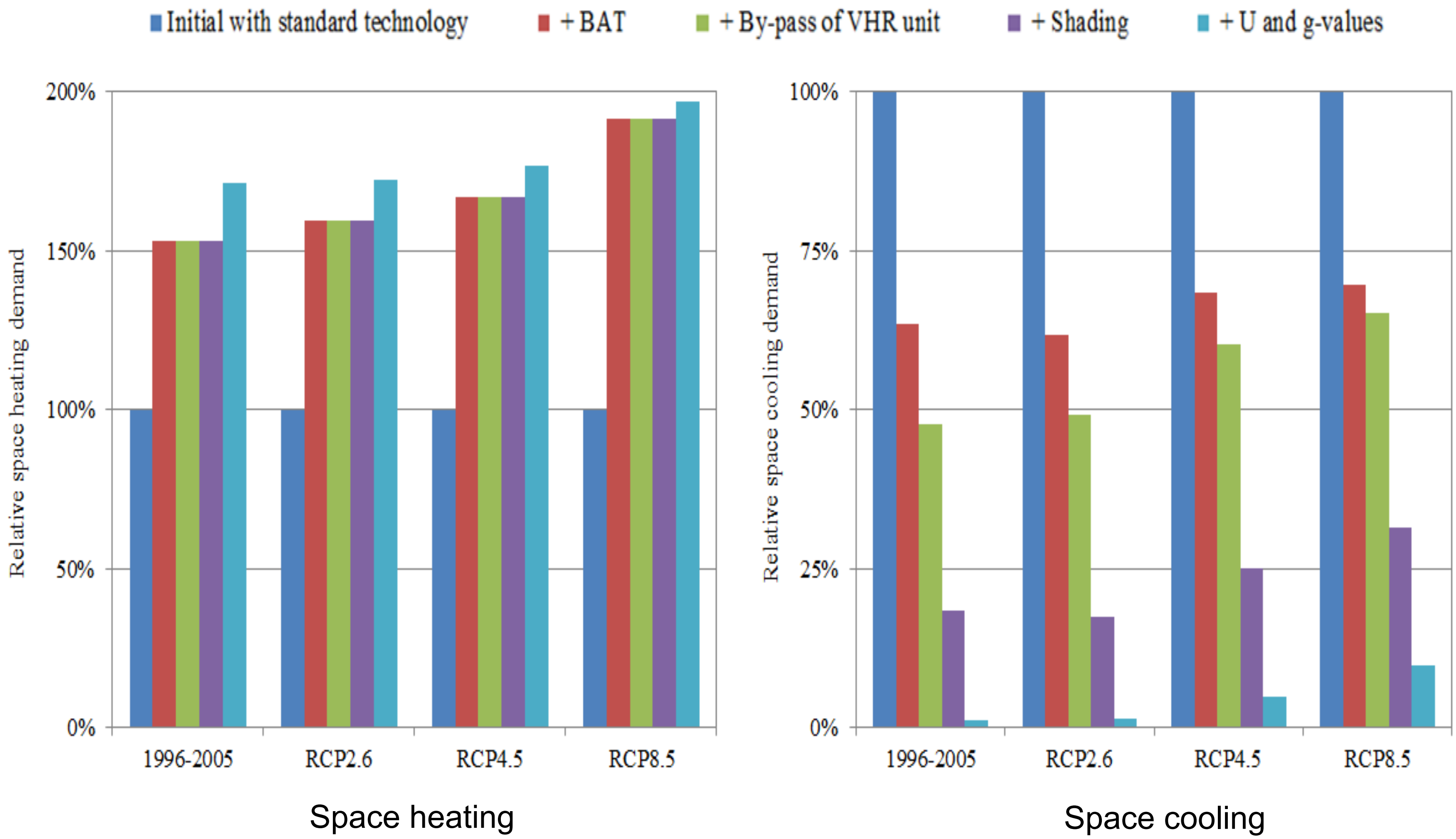
Relative space heating and cooling demand with different strategies under 2050s climate scenarios



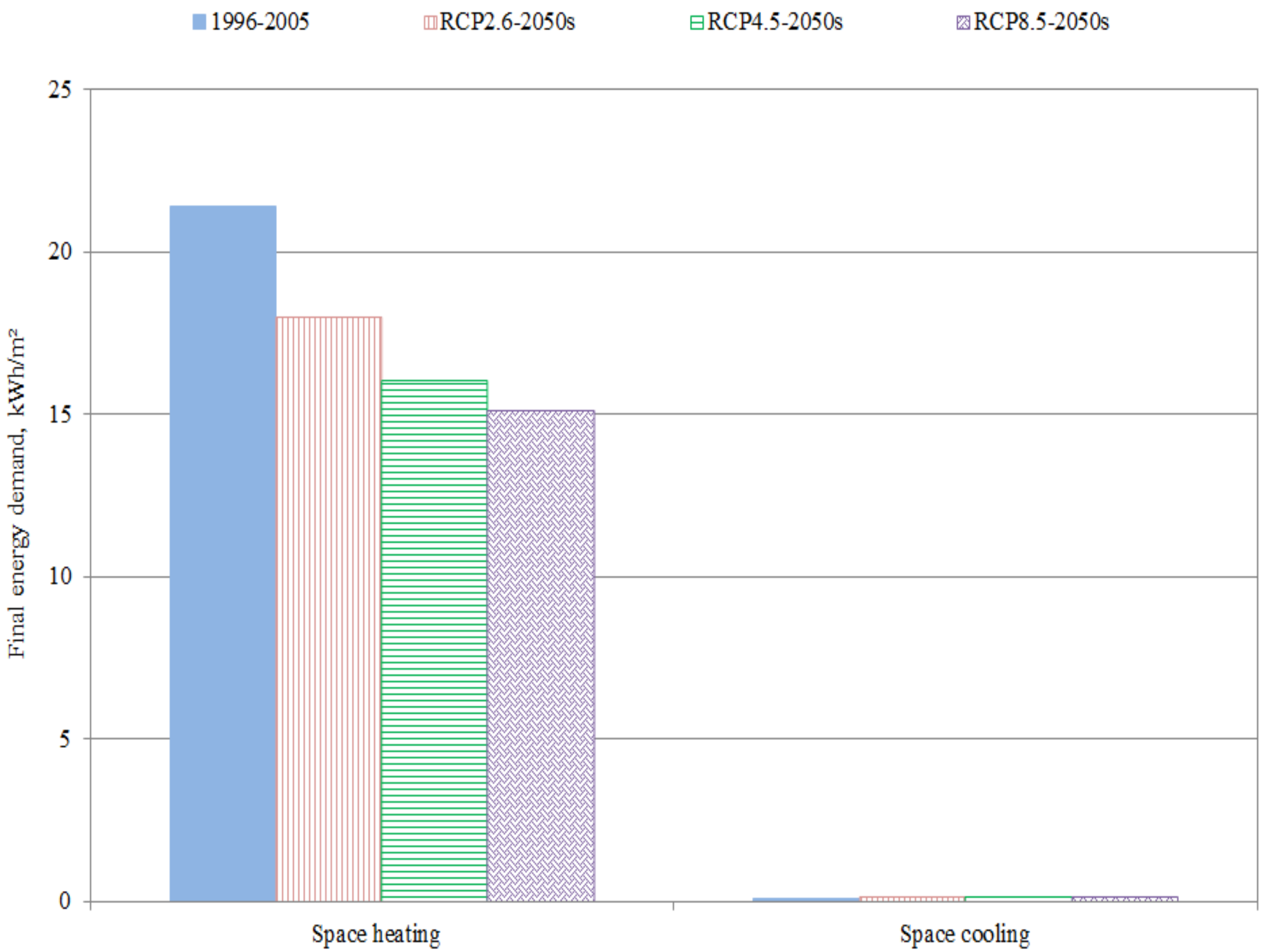
Space heating and cooling demand with different strategies under 2090s climate scenarios



Relative space heating and cooling demand with different strategies under 2090s climate scenarios



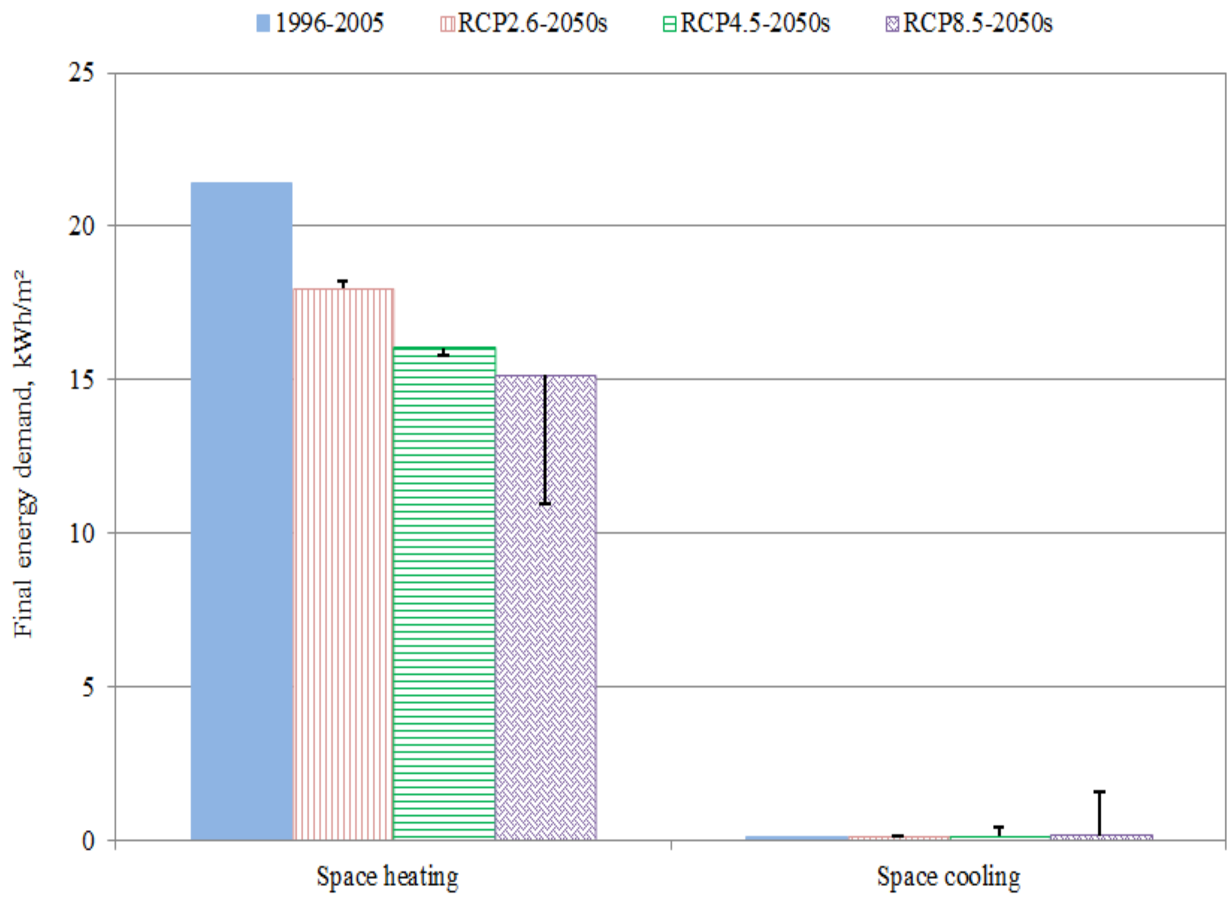
Space heating and cooling demands of the improved* building under different climate scenarios



* Improved passive building version is based on:

- Household equipment and technical installations based on BAT
- By-pass of VHR unit when cooling set point is exceeded
- Solar shading of windows when cooling set point is exceeded
- Window u-values of of 0.6 W/m2/K and g-value of 0.2
- Decreased window areas by 40%
- North orientation for largest window areas

Space heating and cooling demands of the improved* building under different climate scenarios



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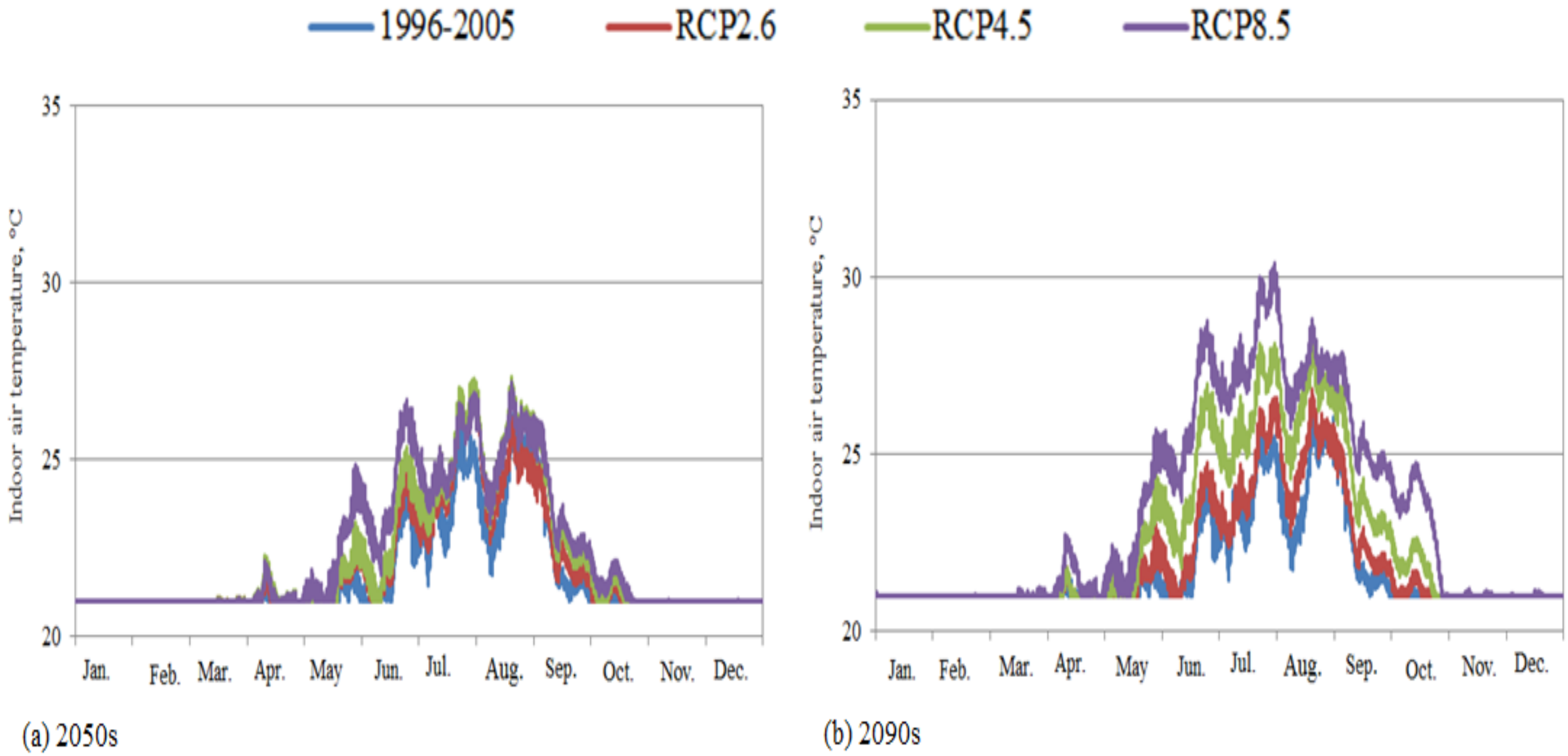
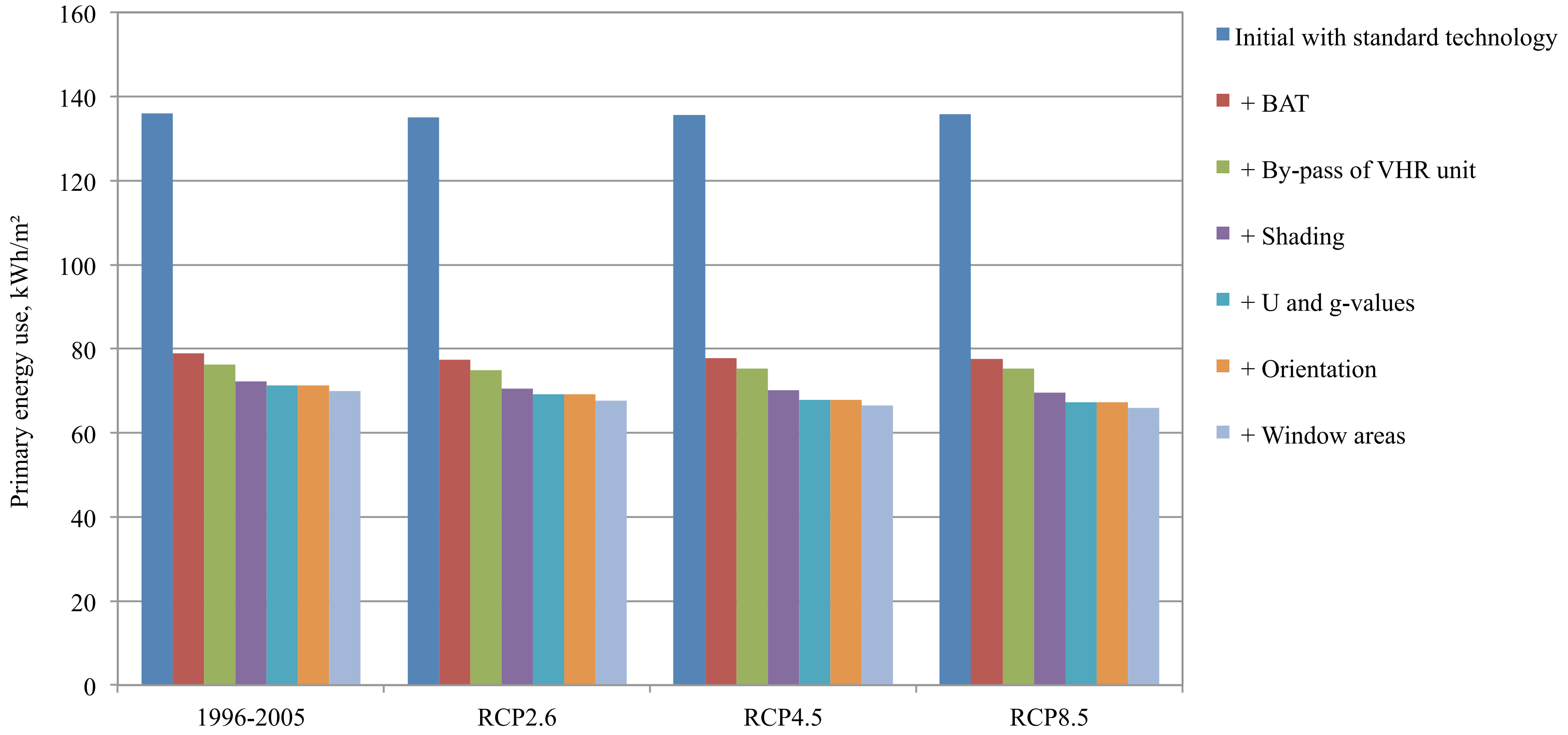
Annual hourly indoor air temperature profile for the improved building under different climate scenarios



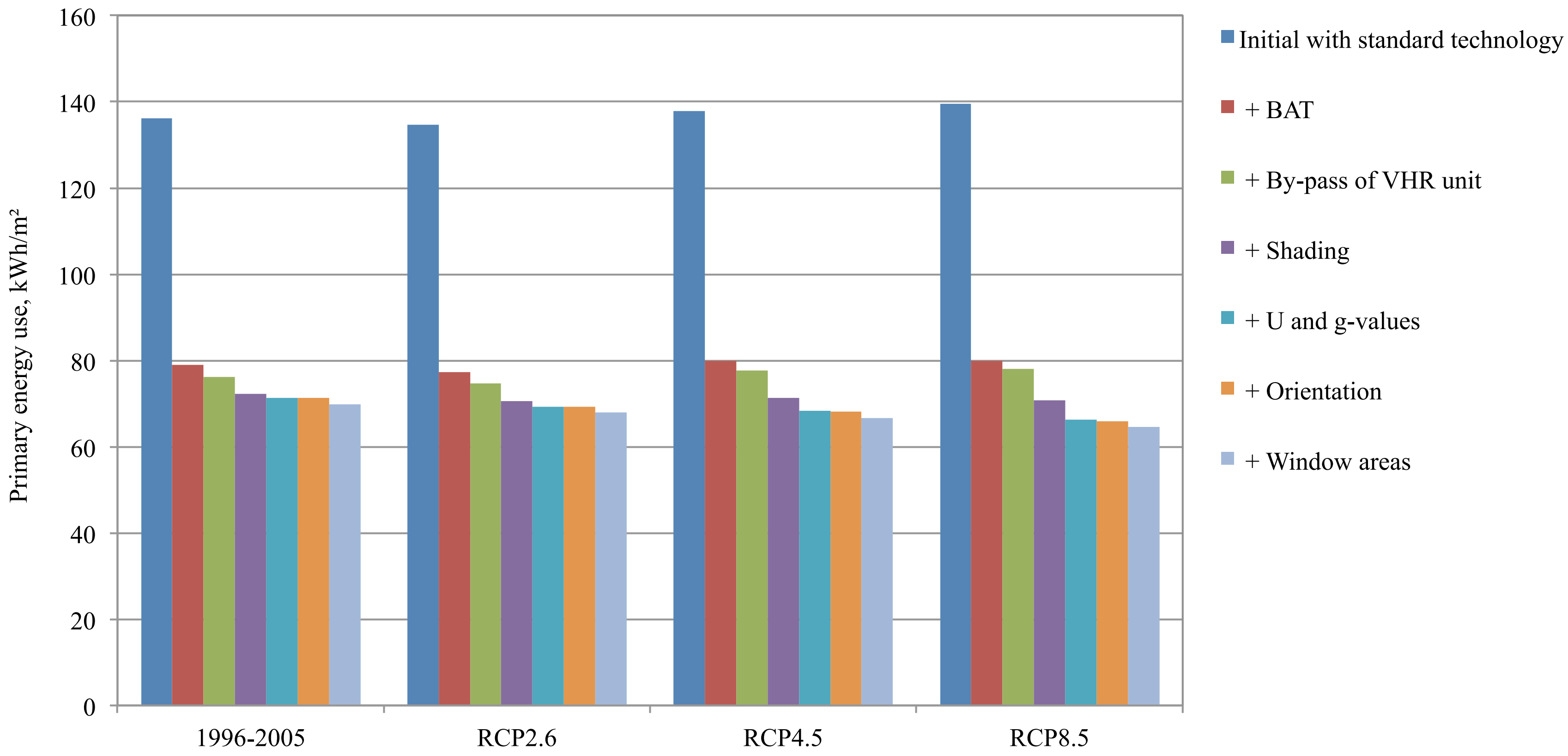
Total annual primary energy use* (kWh/m²) for operation with different design strategies for 2050s



* Includes space heating, tap water heating, electricity for space cooling, ventilation and household equipement and lighting. Space heating is based on CHP.

Air conditioners are assumed to meet the remaining cooling demand after implementing each successive design strategy.

Total annual primary energy use* (kWh/m²) for operation with different design strategies for 2090s



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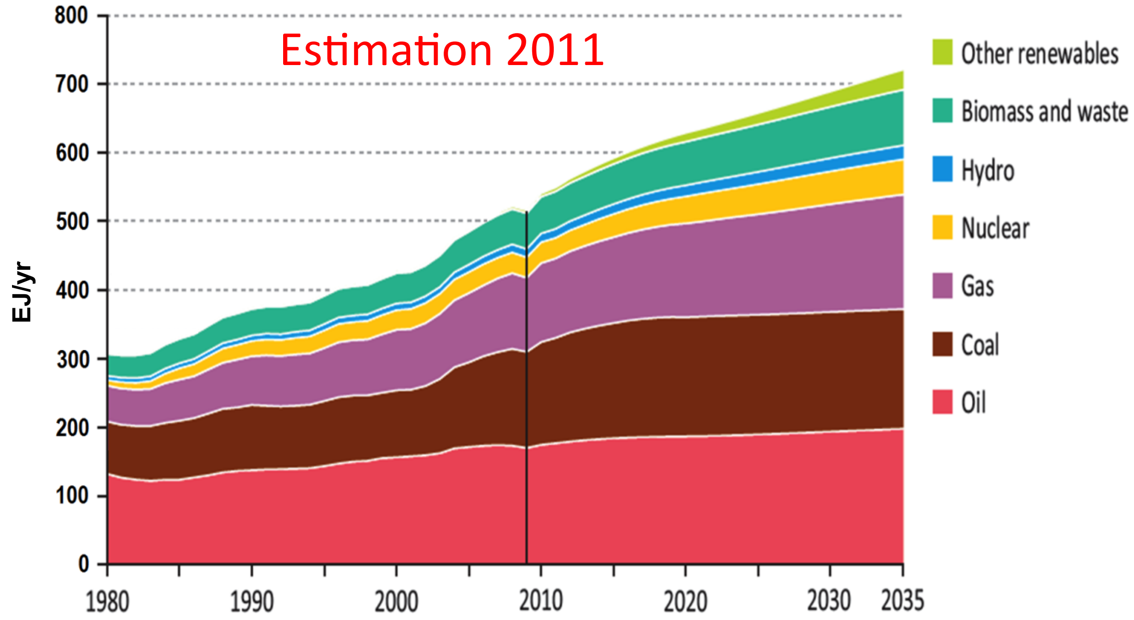
Conclusions

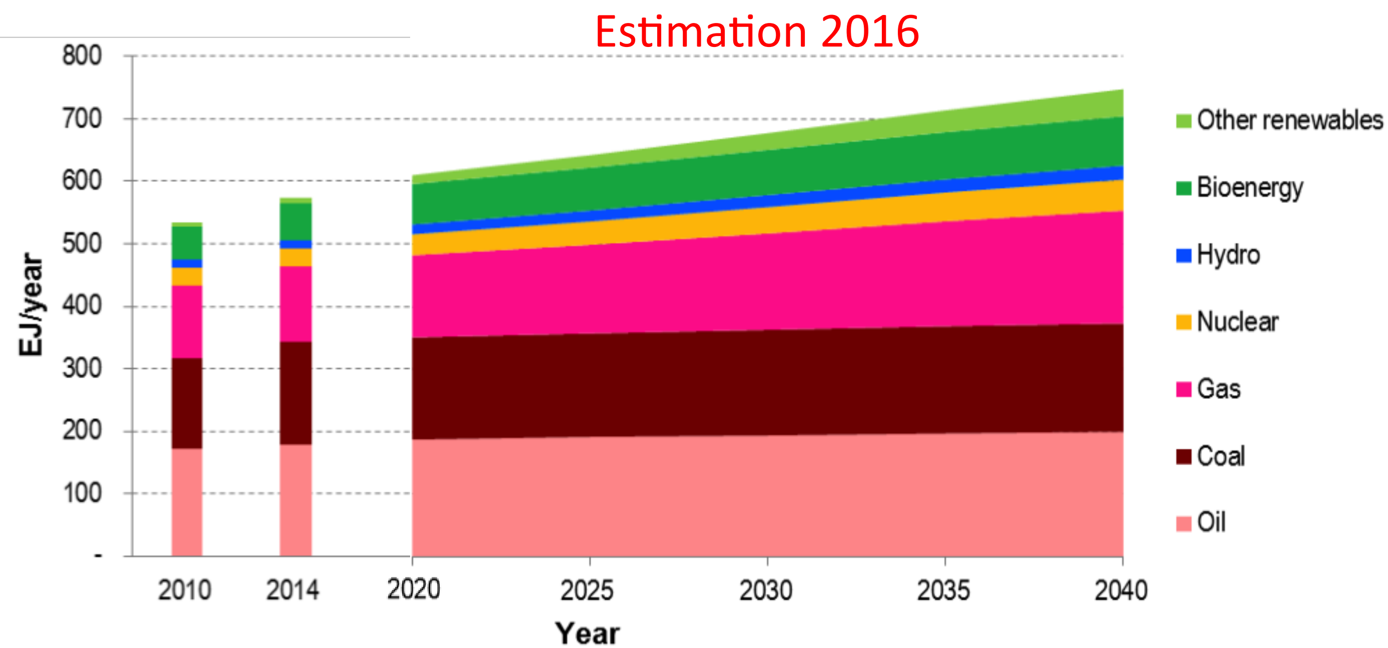
- Significant primary energy reductions are achieved under implemented design strategies
- Overheating hours significantly reduced under implemented design strategies
- Design of new buildings should incorporate appropriate design strategies
- Effectiveness of design strategies should be considered under both current and future climates

Thank you

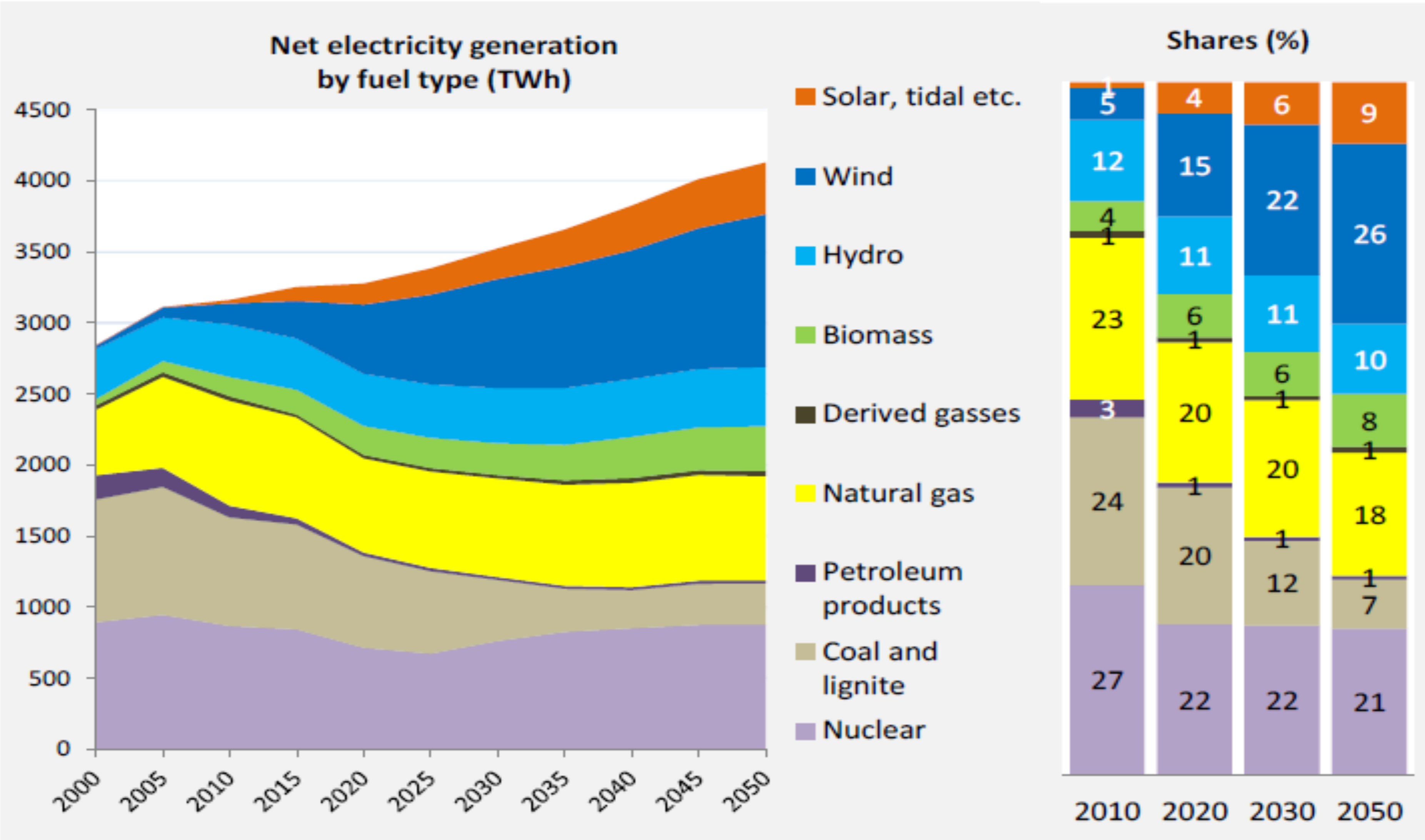
Annual global primary energy use and trends (IEA)



Year	2010	2014
Total (EJ)	**533**	**573**
	Distribution	**(%)**
Oil	32.4	31.2
Coal	27.3	28.7
Gas	21.4	21.1
Total fossil	**81.1**	**81.0**
Bioenergy	10.0	10.4
Nuclear	5.7	4.8
Other	3.2	3.8

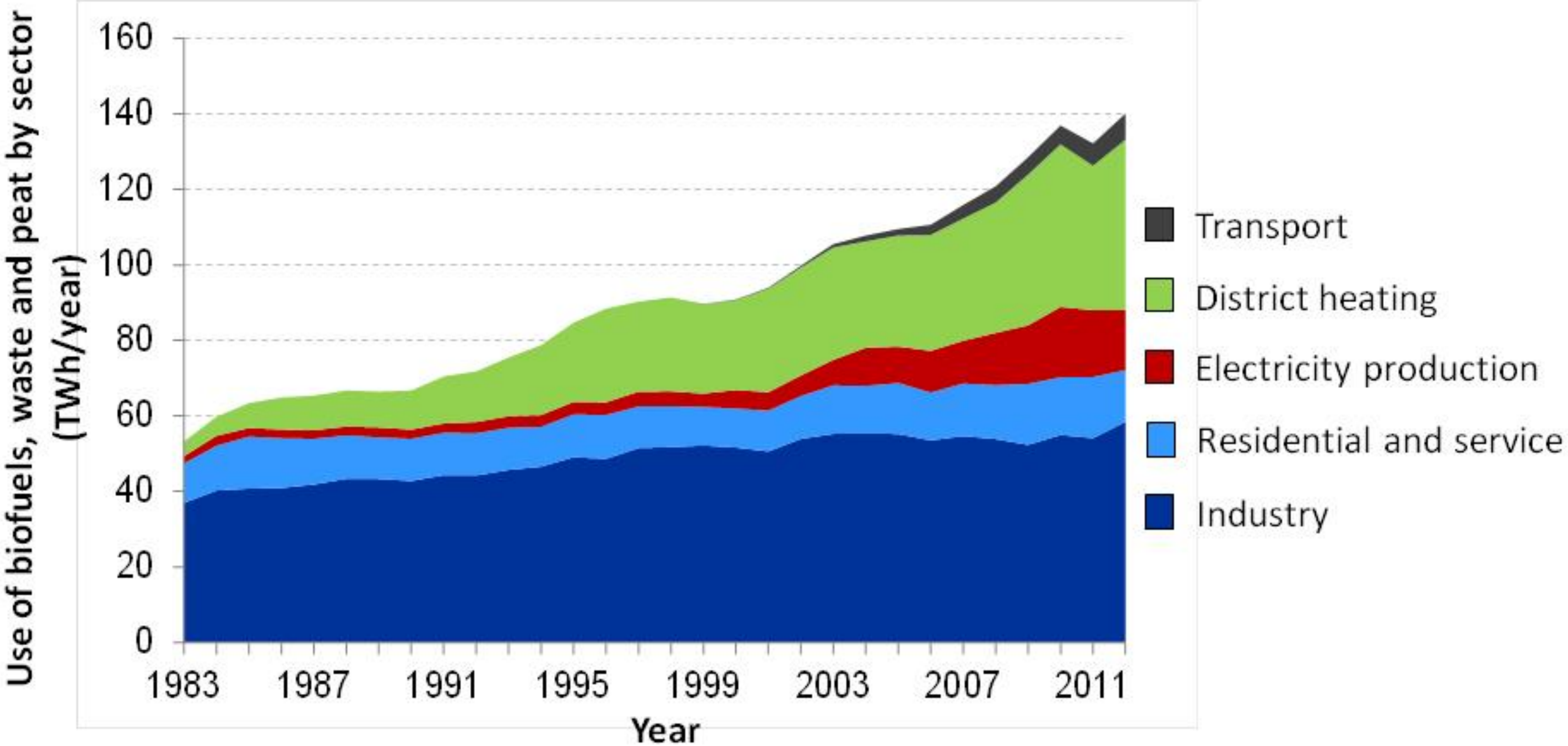


Source: International Energy Agency (IEA), 2011. World Energy Outlook 2011
IEA, 2013. World Energy Outlook 2013;
IEA, 2012. *Key World Energy Statistics*
IEA, 2016. *World Energy Outlook 2016*



Source: European Commission, 2013

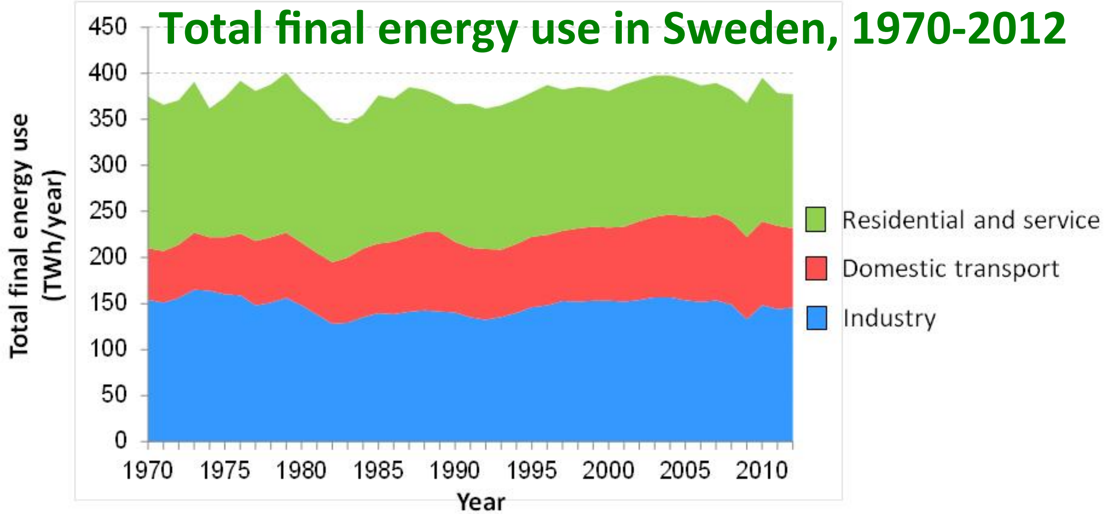
Swedish use of biofuels, waste and peat, 1983-2012



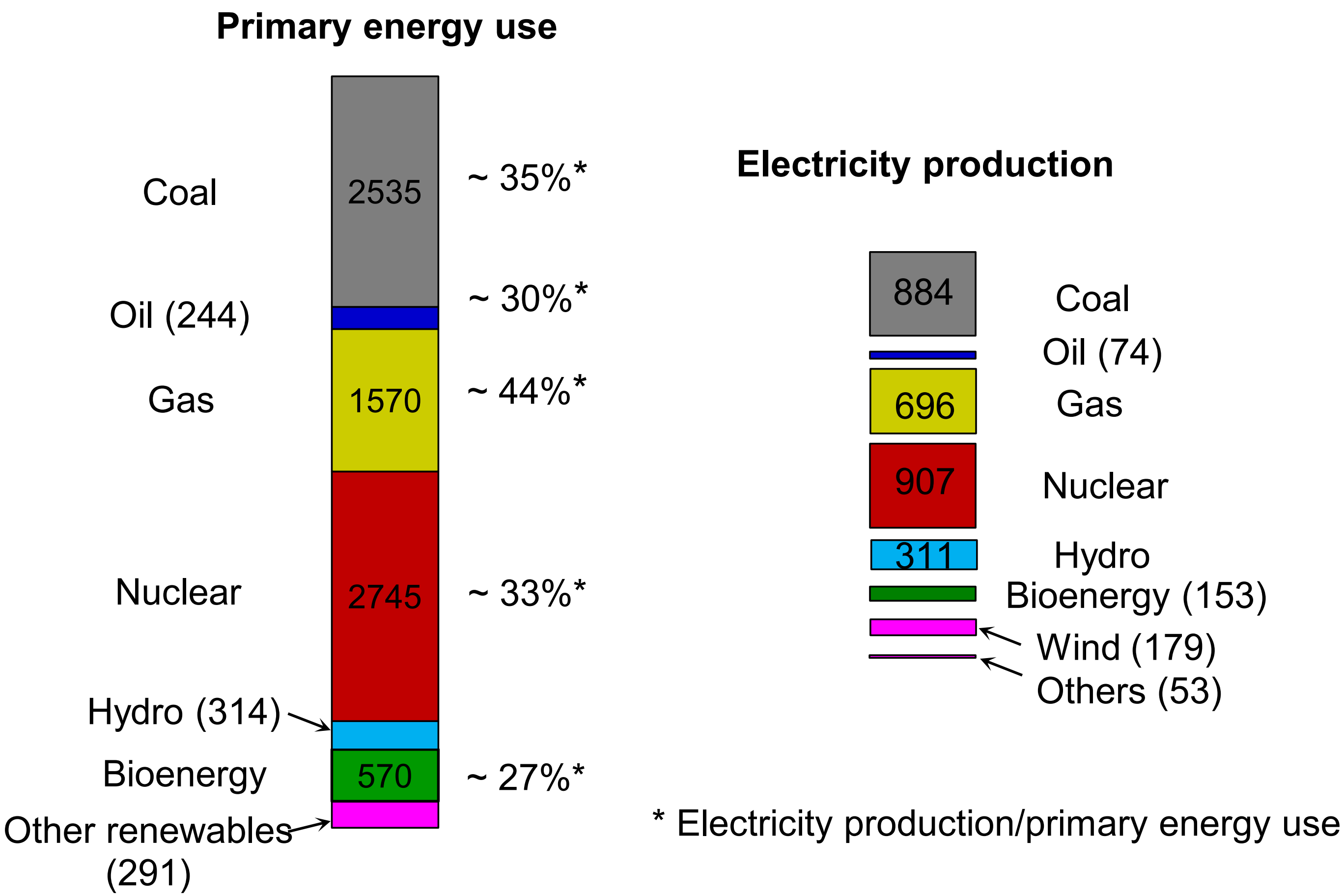
Policy instruments important:

- Energy tax
- Carbon tax
- Renewable electricity certificates

Total final energy use in Sweden, 1970-2012



Primary energy use in EU27 for electricity production and produced electricity in 2011 (TWh)



Source: World Energy Outlook 2013.

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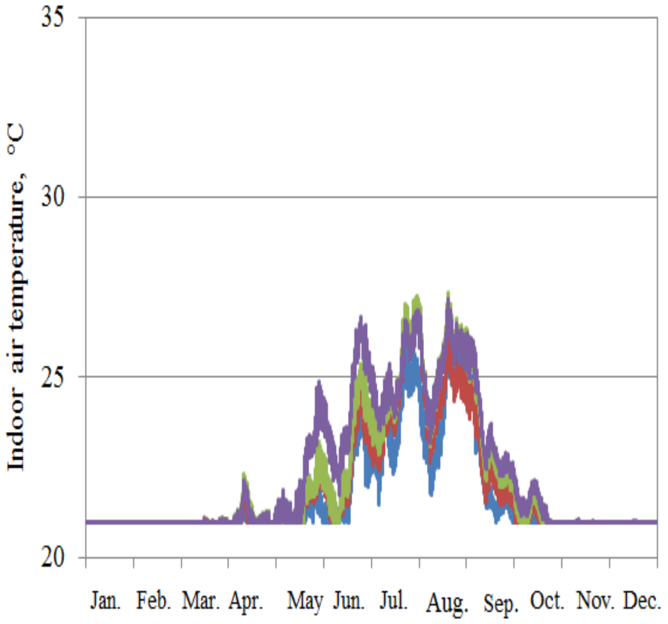
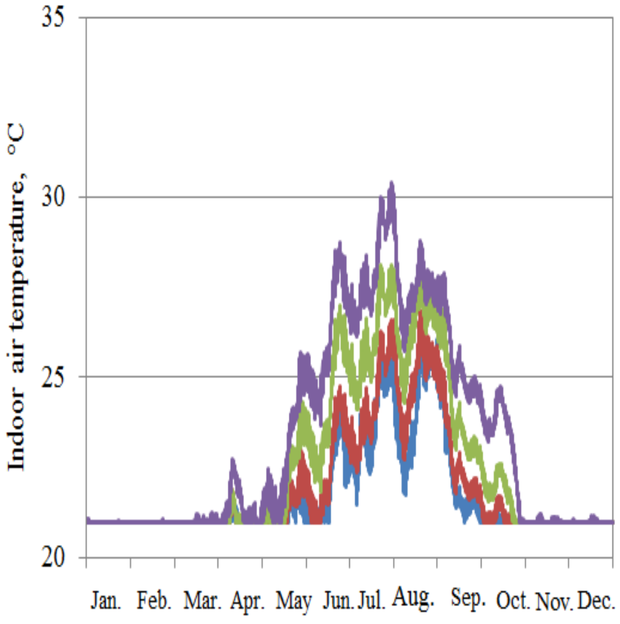


2050s



2090s

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