SPACE HEATING DEMAND IN THE DUTCH RESIDENTIAL SECTOR FROM 1960 TO 2005: A DECOMPOSITION ANALYSIS

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Overview

The evolution of Dutch residential space heating demand was influenced by a complex set of factors over the last half century, including the discovery of the vast domestic gas resources in Groningen, societal trends towards individualisation, and successful diffusion of technological advances such as condensing boilers. This paper uses the Log-Mean Divisia Index I (LMDI-I) methodology to decompose long term trends in space heating demand of the Dutch residential sector from 1960 to 2005. The analysis decomposes change in space heating demand into 4 major components: (1) activity, measured in terms of population, (2) structure in terms of square meters of useful floor area (UFA) per capita, (3) useful space heating intensities, and (4) final space heating intensities in terms of final energy use per UFA. Additionally the impacts of building codes and dwelling stock turnover are analysed and quantified.

Methods

In order to disaggregate long-term trends in Dutch residential heat consumption into its underlying drivers, we apply decomposition analysis techniques. We decompose residential heat consumption into activity, structure, and intensity components. Accordingly, total residential energy consumption E_t is described by the multiplicative contribution of the explanatory variables activity A_t, structure S_t, and intensity I_t.

$$E(t) = A(t) \cdot S(t) \cdot I_{Final}(t) \cdot I_{UED}(t) \qquad \textbf{Equation 1}$$

Activity is measured in terms of population, (2) structure in terms of square meters of useful floor area (UFA) per capita, (3) final energy intensities (I_{final}) in terms of final energy use per UFA, und (4) useful space heating intensities (I_{UED}) (see Equation 1).

For our analysis we use logarithmic mean Divisia index method I (LMDI I) (Ang and Liu, 2001). The LDMI approach is a perfect decomposition technique, i.e. leaving no unexplained residual term in the results. With additive LDMI I decomposition, total change in energy demand (ΔE) from Equation 1, over a time period (t_0 to t_1), is given by the sum of the changes due to changes in activity ($\Delta E_{activity}$), changes in structure ($\Delta E_{structure}$), and changes in intensity ($\Delta E_{intensity}$):

$$\Delta E = E_{t_1} - E_{t_0} = \Delta E_{Activity} + \Delta E_{Structure} + \Delta E_{Intensity} \qquad \textbf{Equation 2}$$

The change in the respective components is calculated as follows:

$$\Delta E_{Activity} = L\left(E_{t_0}, E_{t_1}\right) \cdot \ln\left(\frac{A_{t_1}}{A_{t_0}}\right) \qquad \Delta E_{Structure} = L\left(E_{t_0}, E_{t_1}\right) \cdot \ln\left(\frac{S_{t_1}}{S_{t_0}}\right)$$

$$\Delta E_{Intensity} = L\left(E_{t_0}, E_{t_1}\right) \cdot \ln\left(\frac{I_{t_1}}{I_{t_0}}\right) \qquad \textbf{With :}\ L\left(E_{t_0}, E_{t_1}\right) = \frac{E_{t_1} - E_{t_0}}{\ln E_{t_1} - \ln E_{t_0}}$$

In order to avoid short-term fluctuations (e.g. due to imperfect climatic corrections, behavioural factors etc.) and for sake of robust trend observation we apply the decomposition analysis to 3 years moving average values of the respective factors. Besides the decomposition analysis, with is rather top town in nature, we provide a number of available bottom-up information such as heating system diffusion and efficiencies, envelope improvements and building stock dynamics. The purpose if this bottom up information is twofold: firstly validate the top down information and, secondly, provide additional insight into the causal relationships.

Results

The results of the decomposition analysis are given in Figure 1. As the analyses are based on the 3-year running average the base year is 1962, which is the mean of ’60, ’61 and 62. The contribution of the different factors (activity, structure etc.) is shown separately for each factor. In addition the net change relative to the base year (ΔE), which follows as sum of the changes due to changes in the respective factors (see Equation 2), is shown.

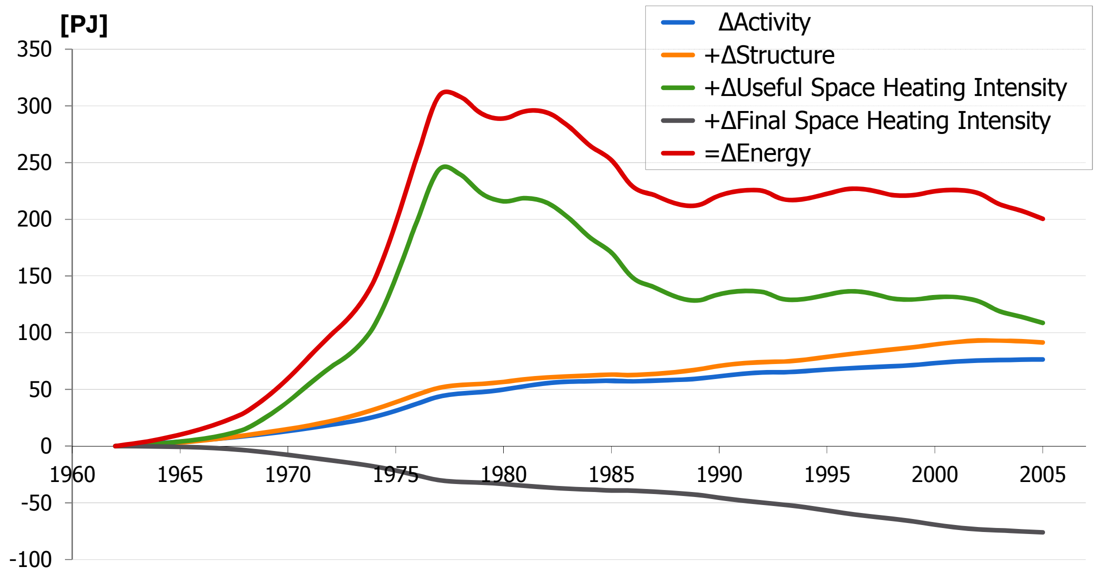

Figure 1: Factorial decomposition of residential space heating demand in the Netherlands 1962-2005 (3 years moving average)

The results are presented in physical units (petajoule). It is conspicuous that energy consumption soared from the beginning of the 1960ies to a plateau of roughly 300 PJ in the mid-1970ies. The corresponding logarithmic growth rate is more than 30%, implying a doubling every 2 years. From the consumption plateau, however, space heat demand declines rapidly up to the mid-1980ies and from there on decreases only slightly.

Conclusions

The analyses revealed that useful space heating resemble an inverse-U-shaped pattern. From 1960 useful space intensities soared with 30% annually to a plateau in 1970ies and thereafter declined continuously with diminishing rates of improvement. However, useful space heating intensity is still the dominating factor with respect to energy demand increases relative to the base year. Population growth (activity) and increasing per capita floor space demand (structure) continuously increased demand for space heating relative to the base year over the entire horizon. The combined contribution of activity and structure is roughly of the same order of magnitude as useful space heating intensities. Conversely, however, final space heating intensities, tracking the change heating systems’ efficiencies, continuously improved over the entire horizon analysed. The major technological improvement was the successful and widespread diffusion of condensing boilers. Building codes were successful in damping demand growth, but contributed only little to the overall reduction of the average demand per dwelling as dwelling stock turnover is slow.

References

Ang, B.W., Liu, F.L. (2001). A new energy decomposition method: Perfect in decomposition and consistent in aggregation. Energy 26, 537-547.