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Enhanced EU policies required for passive house standard by 2050

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Abstract

This work presents an empirical analysis of unit consumption (kWh/m^2/year) of final energy demand for space and water heating from 1970 to 2005 in the residential sector of four EU countries; France, Italy, Sweden, and UK. Unit consumption is modelled as it is an internationally accepted indicator of energy efficiency in buildings and is a benchmark standard for passive houses in Northern Europe. Cointegration analysis is used to handle the general non-stationarity of dependent and explanatory time series variables. The modelling results yield that the annual price increases that would be necessary to reduce unit consumption of final energy demand for space and water heating below 30 kWh/m^2 (15 kWh/m^2/year for space heating plus a further 15 kWh/m^2/year for water heating) by 2050 are 20 % 11 %, 11 %, and 18 % for the four countries respectively. In fact at a 3 % per annum price increase to 2050, which would be unprecedented over 45 years compared to the period 1970 to 2005, unit consumption falls to 75 kWh/m^2; 75 kWh/m^2; 65 kWh/m^2; and 95 kWh/m^2 for the four countries respectively. This suggests both an upper limit of a price effect and indicates the need for strong non-price policies if by 2050 unit consumption of final energy demand for space heating is to be reduced close to the passive house standard of 15 kWh/m^2/year.

Introduction

Lowering absolute energy demand in dwellings is a key policy goal of the EU. In the short term the indicative goal for 2020 is to lower primary energy demand in the residential sector by 27 % (EC, 2006) while the long term goal is expressed in terms of a strategy for reducing CO2 emissions from the sector by 90 % by 2050 compared to 2005 levels (EC, 2011). These structural shifts are to be achieved by improvements in the thermal efficiency of existing dwellings, shifting fuel use towards more energy efficient and less carbon intensive fuels and ensuring that dwellings built from 2021 onwards are nearly zero-energy buildings (EC, 2011). The level of thermal efficiency to which existing buildings are to be renovated is an on-going academic and policy discourse. The main argument against so-called "deep renovation" is that from a systems perspective that it may be cheaper to undertake a moderate level of renovation and to then supply renewable electricity or heat to buildings for their remaining energy requirements. An argument for deep renovation is that existing buildings will have to be renovated sooner or later and that if they are not renovated to a high energy performance, that the lost savings opportunity will be "locked in" to the buildings for a further 30 years or so until the next renovation cycle comes (Ürge-Vorsatz et al,2011). Regardless of ones position on the spectrum of views between deep and moderate renovation, the slow rate of stock turnover (Enper-Tebuc, 2003) means that there is acceptance that reducing energy use in *existing* dwellings should be the main focus of policy efforts. The most common indicator used to assess the degree to which renovation has lowered energy demand is *unit consumption* of final energy demand for space heating. The unit in this case is a square metre of heated floor space. A unit consumption of 15 kWh/m^2/year or less is the generic passive house standard for space heating in Northern Europe (Feist, 2010). This paper presents an econometric analysis of the dynamics of unit consumption of final energy demand for space and water heating (unit consumption) between 1970 and 2005 for four EU countries. Results are used in scenarios of unit consumption to 2050. The aim of the paper is to assess what reductions in unit consumption can be expected given its historic dynamics and different levels of future price rises i.e. how close to the passive house standard can unit consumption be expected to come in the long term given alternative energy price scenarios. The work augments the econometric modelling of energy efficiency undertaken by Haas and Schipper (1998) and Nässén et al (2008) by including cointegration analysis and extending the time series used to 2005. The paper also compares results to EU Energy aspirations.

Madlener and Clements (1999) have shown that the use of a Box Jenkins SARMA regression model is most accurate for the kind of future demand estimations carried out in this work. In Box Jenkins models future estimations of demand are based on past values of demand weighted by a coefficient. This approach avoids the need to estimate future levels of other variables e.g. prices and income, in order to estimate future levels of demand. However, for the work described in this paper it is desired to estimate the role of energy prices explicitly and thus a model that has energy prices as an explicit determinant of energy demand is adopted. A dynamic econometric model is adapted to determine short- and long term elasticities because in the short term there may be lock in effects of in-situ heating systems which lead to a delayed reaction to price dynamics.

Chateau and Lapillonne (1978) suggest that using econometric models for energy demand forecasting should be restricted to 5 to 10 years into the future because such models cannot account for structural changes which are inevitable over longer time periods. For forecasting over longer time periods they suggest the disaggregation of energy demand into structural components of the economy e.g. demographics, and the creation of scenarios for their development. In their approach, econometrics can be used to model homogenous individual structural components e.g. energy efficiency or unit consumption.

Methodology

Unit consumption (kWh/m^2/year) for final energy demand for space and water heating in the residential sector is modelled for four EU countries; France, Italy, Sweden, and UK using an autoregressive distributed lag (ARDL) linear regression approach as follows:

$$\boldsymbol{ln(I_t) = \alpha_0 + \alpha_1(t) + \sum_{i=1}^{p} \Phi_1 ln(I_{t-i}) + \sum_{i=1}^{q} \beta_1 ln(P_{t-i}) + \sum_{i=1}^{q} \beta_2 (HDD_{t-i}) + e_t} \qquad (1)$$

where I_t, P_t and HDD_t are the absolute values of unit consumption, energy prices and heating degree days respectively. Equation (1) is adopted from Bentzen and Engsteds (2001) econometric model of energy demand with the main difference that income is not included as an explanatory variable. This is because it is assumed that income is an explanatory variable of total energy demand via its influence on the dynamics of floor area per household, but that its influence on unit consumption is considerably lower. Equation (1) is also similar to the models used by Haas and Schipper (1998) and Nässén et al (2008). Time series data from 1970 to 2005 are applied to Equation (1) to obtain price and other elasticities that explain the historic dynamics of unit consumption. A time series of this length is justified to capture both the sharp energy price increases of the 1970's and the relatively flat energy prices of the period from the mid 1980's on. As is standard with ARDL models the value of the long- run price elasticity of demand for unit consumption is given by $\beta_1/(1-\Phi_1)$. The number of lags is chosen (P, Q over summation symbols in Equation (1)) so as to eliminate serial correlation of errors (e_t). Cointegration analysis is used to handle the general non-stationarity of dependent and explanatory time series variables.

The countries modelled (France, Italy, UK, and Sweden) are chosen because of the availability of relevant data extending back to 1970´s, their diversity in terms of climate and the degrees of housing insulation, and the fact that the first three countries listed account for approximately 40 % of the total energy demand of the EU residential sector. Time series data for I_t, and HDD_t are obtained from the Odyssee database(2008) and from Schipper (2010). P_t is a weighted average price (WAP) for energy for space and water heating. Household energy carrier prices from 1970 to 2005 used to construct the WAP are obtained from IEA (2008) and Schipper, (2010). Consumer price indices obtained from OECD, (2008) are used to normalise prices to year 2005. The IEA provides historical prices for coal, electricity, gas and oil, but not for biomass or district heating (DH). Prices for biomass and DH in Italy and UK were not needed due to the lack of penetration of these two energy carriers in these countries. Prices for DH in France and Sweden were obtained from Werner (2009). For Sweden, biomass prices were based on the data provided by Björheden (2006) and Junginger et al (2005). Thus, for France, the options were to include biomass in the energy demand time series but not in the weighted average energy price time series or to omit biomass from the energy demand time series; tests to discover the best-fit model led to the latter option being chosen. For a review of the data availability for this type of work for any European country, see Ó Broin (2007).

The original motivation for examining the demand for both space and water heating is that the data for these two end uses have not been collated separately in Sweden, as much of the demand for both end uses is met with hot water provided via district heating. For the other three countries, this is not the case. Therefore, it can be argued that separate models for space and water heating should have been created for these countries. For consistency and to allow for the inclusion of Sweden in the present study, given the importance of its unique climate and housing insulation levels, it was decided to investigate the demand for both space and water heating for all four countries.

The time series were tested for stationarity and cointegration using the Augmented Dickey Fuller (ADF) version of the unit root test (Enders, 2004). The tests revealed that all the time series of HDD were stationary, whereas most of the time series for the other data categories contained one unit root. Tests also revealed that the vector proposed for Equations (1) ($1, \alpha_1, \beta_2, \beta_3$) is cointegrated, i.e. it is not a spurious regression and a long-run relationship exists between these variables (Ó Broin, 2013a).

Once price and other elasticities of demand have been obtained i.e. values for $\alpha_0, \alpha_1, \beta_2, \beta_3$, three scenarios for the development of energy prices are applied to estimate unit consumption from 2006 to 2050. In doing so the coefficient of HDD (β_2) is suppressed and α_0 adjusted accordingly, since the role of HDD in Equation (1) is to establish realistic price elasticities. In addition, climate-corrected measured data for 2005 is used as the lagged input (I_{t-1}) in the estimation of unit consumption for

2006. Rather than estimate what future prices will be, a range of future prices are used with the hope that the range selected contains the prices which can be envisioned in future; 1) prices remain the same; 2) prices increase by 2% per year; and 3) prices increase by 3% per year for the weighted average price of energy from 2010 onwards. These three price scenarios match somewhat with those used in the POLES global model for the EU Roadmap (EC, 2011). The justification for using a range of annual price changes of between 0 % and 3 % as scenarios in this work is that although average annual price increases of between 5 % and 10 % occurred in the 1970's a 3 % per annum price increase over 45 years would be unprecedented[1].

Results

Unit Consumption

Table 1 presents the results for the ARDL linear regression model of unit consumption, based on Equation (1). The Adjusted R^2 and F-test statistical values obtained are high, meaning that the explanatory variables explain most of the dynamics of unit consumption individually and in tandem.

Table 1 : ARDL Model of Unit Consumption[a].

Unit Consumption	France	Italy	Sweden	UK
α_0 (Constant)	9.04	4.91	14.10	20.49
α_1 (Trend)	**-0.0035** (3.04)	**-0.0011** (0.47)	-0.0053 (2.48)	-0.0072 (6.65)
Φ_1 (Lag)	**0.64** (5.04)	**0.59** (4.77)	0.49 (4.02)	0.012(0.13)
β_1 (Price)	-0.060 (1.79)	-0.14 (3.02)	-0.14 (3.97)	-0.21 (6.50)
β_2 (HDD)	0.00029 (12.80)	0.00013 (1.37)	0.000076 (2.92)	0.00021 (8.32)
Lag HDD	-0.00018 (3.14)	--	--	--
Long-run Price	**-0.17**	**-0.35**	-0.27	-0.21
Adjusted R^2	0.98	0.95	0.98	0.94
F-test statistic	313	147	314	105
Durbin h statistic	1.23	1.39	1.30	0.76
Degrees of freedom	24	30	30	28

[a] The input data for Italy and Sweden are from 1970 to 2005, those for France are from 1975 to 2005, and those for the UK are from 1973 to 2005. Heteroscedasticity robust critical t-statistics are given in parentheses. One augmentation lag was needed to ensure elimination of serial correlation for Italy, Sweden, and the UK, while two augmentation lags were needed for France.

The short-term price elasticities of demand ranged from -0.06 for France to -0.21 for the UK. These elasticities are low but are not dissimilar to the results obtained in other studies (Athukorala and Wilson, 2010, Haas and Schipper, 1998 and Nässén et al., 2008). The variability of these results, with lower elasticities observed for France, Italy, and Sweden compared with the UK, may be due to the former three countries having larger home rental sectors in which tenants have fixed costs for heating. Furthermore, Prices have actually fallen in France between the mid-1980s and 2004, which would also result in low price elasticity. The large share of electricity use in France for space and water heating may also have had an impact. Coefficients for the time trend were found to be of the same order of magnitude for each country, although they ranged from -0.001 (-0.1%) in Italy to -0.006 (-0.6%) in the UK, suggesting that the effects of technical change and regulations have not been as pronounced in Italy. The coefficients of HDD are of similar order of magnitude and are

[1] The annual percentage price change between 1970 and 2005 is highly influenced by the average annual price change between 1970 and 1982 (France: 10.73%, Italy: 9.18%, Sweden: 8.17, UK: 3.25%) while the average annual price change is negative for three of the countries between 1983 and 2005 (France: -0.93%, Italy: -0.17%, Sweden: 0.62, UK: -0.78%).

highest for France and surprisingly lowest for Sweden, which has the coldest climate, i.e., the impact on unit consumption of the colder winters between 1970 and 2005 has been least potent in Sweden. This may be due to the higher levels of insulation in houses in Sweden[2] and the widespread use of district heating. The coefficients of the lag are similar for France, Italy, and Sweden, while they are negligible for the UK. The long-term price elasticities, which range from -0.17 for France to -0.35 for Italy, show that in the long run Italy and Sweden “catch up with and overtake” the UK in terms of response to price changes, whereas in France the effect is less pronounced, presumably reflecting its large share of electricity use for space and water heating.

The multicollinearity (correlation) of the explanatory variables presented in Table 3 was checked by calculating the variance inflation factor (VIF) for each. Results show the presence of multicollinearity for the trend and lag parameters for France and Italy. The coefficients of these parameters are thus highlighted in Table 3. Although it is assumed that the presence of multicollinearity does not negatively affect the ability of the model to be used for forecasts (Gujarati, 2006) the individual coefficients (trend and lag) may be biased. As the lag is involved this has implications for the bias on the long term price elasticity calculated for these two countries as well.

Haas and Schipper (1998) reported a short-term price elasticity of -0.11 for Sweden and the UK but showed insignificant elasticity coefficients for France and Italy. This result for Sweden is similar to that obtained in the present work, whereas the value obtained previously for the UK is lower than that obtained for the UK in the present work. However, Haas and Schipper (1998) found that the short-term and long-term elasticities for the UK were almost equal, which is similar to the finding of the present work. The discrepancies between the previous and present studies may be attributed to the time series used by Haas and Schipper being shorter (1970-1993) and the fact that they studied the elasticities of all end-uses, i.e., not just space and water heating.

As described in Sections 2.1 and 2.2, income is included as an independent variable for unit consumption, but only to explain the development of floor area. This means that the risk of multicollinearity between income and the time trend is avoided. Nonetheless, tests to include income gave results that were difficult to interpret or to relate to any theoretical understanding: for Sweden and the UK, income was not significant in the regression analysis and its inclusion had almost no impact on the other coefficients; for France, the income elasticity was positive and for Italy, it was negative. For the latter two countries, the inclusion of income also reduced the price elasticity and its level of significance. The inclusion of income reduced the F-test statistical values of the regressions for all the countries, with the exception of France, where it resulted in a slight increase.

[2] Werner (2006) suggests that the difference in unit consumption between say Sweden and Italy is related to the square root of the number of heating degree days rather than the actual number of heating degree days, due to the higher insulation standards in Sweden.

Scenarios

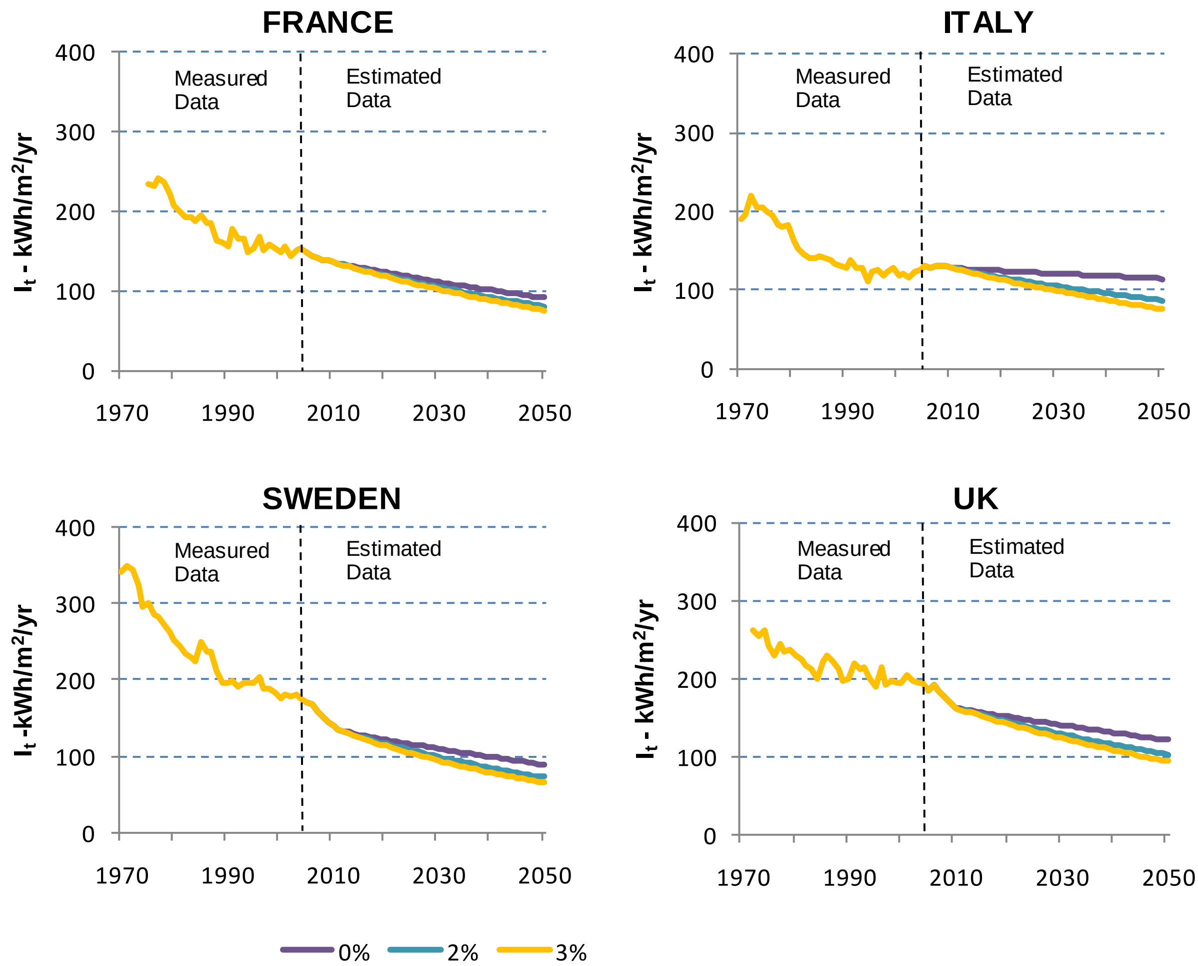

Figure 1 : Scenarios for unit consumption, I_t, from 2006 to 2050.

Figure 1 shows the scenarios made for unit consumption from 2006 to 2050 obtained using the coefficients described in Table 1 and the three price scenarios. Figure 1 also includes measured data from 1970 to 2005 (1975 for France and 1972 for the UK). Depending on the price scenario chosen for the four countries, unit consumption decreases as follows: for France, from 150 kWh/m^2 to between 90 kWh/m^2 and 75 kWh/m^2; for Italy, from 131 kWh/m^2 to between 90 kWh/m^2 and 75 kWh/m^2; for Sweden, from 171 kWh/m^2 to between 90 kWh/m^2 and 65 kWh/m^2; and for the UK, from 184 kWh/m^2 to between 120 kWh/m^2 and 95 kWh/m^2. In the high price scenario, these figures represent approximate average annual demand decreases of 1.5% for France and the UK, 1.2% for Italy, and 2% for Sweden or overall reductions in demand of 50%, 42%, 38%, and 51%, respectively. Although the price elasticities used in these scenarios are highest for Italy and lowest for France (see Table 1), the results obtained are also determined by the effects of trend, lags, and HDD, and suggest that on the whole there is a higher sensitivity to changes in these parameters in Sweden than in the other three countries.

As the lowest level of unit consumption reached in the four countries by 2050 is 60 kWh/m^2/year, it can be concluded that the level of unit consumption calculated in this work for 2050 is quite different from the passive house standard notwithstanding that a proportion comes from water heating. Hence, as expected the three annual price-change scenarios are far from sufficient to reduce unit consumption to passive house standard. The annual price increases that would be necessary with the coefficients in Table 1 to reduce unit consumption for space and water heating below 30 kWh/m2 are 20 % 11 %, 11 %, and 18 % for the four countries respectively. Given that the 3% annual increase in energy prices is historically high for a period of 45 years, additional policy measures and regulations are obviously required to achieve such targets. On the other hand the value for energy use for space and water heating of 65 kWh/m2 for Sweden in 2050 obtained in this work may represent a sustainable solution from the emissions and systems perspectives, given the abundance of carbon-neutral district heating in this country. Furthermore, the new EU directive on Energy Efficiency (EC, 2012) wants member states to carry out a comprehensive assessment of the potential for the application of efficient district heating and cooling, suggesting that “renovation to passive” may not be the only sustainability option considered at a policy level.

DISCUSSION

While increasing energy prices have a significant impact on energy demand in the scenarios for all the countries, it is noteworthy that even the scenarios with zero increases in energy prices show considerable reductions in unit consumption. Comparing the scenarios of 0% and 3% increases in energy prices per annum, the price increase accounts for only around half of the reduction between 2005 and 2050 as shown in Figure 1 (France, 20%; Sweden, 30%; the UK, 30%; and Italy, 70%).

The reason for this is the impact of the time trend coefficient, as included in Equation (1). The question then arises as to how this result should be interpreted. The time trend coefficient captures gradual changes in unit consumption over time that cannot be attributed to changes in prices or climate (heating degree days). That a large part of the reduction in unit consumption is attributed to the time parameter does not mean that this reduction occurs “by itself” as time passes. Non-price policy measures have certainly affected the gradual energy efficiency improvements seen in the past and they are also indirectly incorporated into the time trends of the scenarios.

Examples of such policies include energy standards for new buildings, support for the development of new technologies, and subsidies for technology diffusion. Nässén et al (2005) estimated that between 1975 and 2000, about one third of the energy efficiency improvements in the Swedish residential building stock were due to the addition of new, more energy efficient buildings. In the absence of a strategy for continually strengthening the energy standards for new buildings or the support for energy efficient buildings, such as passive houses, the addition of new buildings may simply contribute to increasing floor areas rather than lowering the average unit consumption of the entire stock. The correct interpretation is then that in order to achieve the reductions in energy demand suggested by the time trend, non-price policies will have to continue according to historical patterns (note that energy efficiency in building has been an important policy issue since the oil crises of the 1970’s). If future policy making in this sector will rely solely on the price mechanism, then the scenarios presented in Figure 1 will need to be corrected upwards i.e. would show less energy savings to 2050.

What is thus the price effect shown in this paper? Increasing energy prices from the low-price scenario to the high-price scenario offers a gain of around 25 kWh/m^2, i.e., a further reduction in unit consumption. This is significant in itself, but, in the context of average unit consumption of over 130 kWh/m^2 in 2005, this would not be enough to reduce unit consumption to passive house standard for the 45 year period studied (See Figure 1). The long run price elasticity is low (mean of -

0.25 over the four countries) and it has been calculated in this paper that annual prices rises of over 10 % would be necessary to reduce unit consumption below 30 kWh/m^2/year by 2050. Over the period 1970 to 2005, the only sustained time when price rises of over 3 % per annum occurred was during the two major oil crises of the 1970´s (see footnote 1). The fuel mix for heating in the four countries examined in this work has diversified since the 1970's to include more natural gas, biomass, electricity and district heating. Global reserves of natural gas, which account for nearly half of the fuel used for heating in the four countries combined, are increasing while its price is decoupling more and more from that of oil (IEA, 2012; Kjärstad et al., 2013). Thus one may assume that price "crises" such as occurred in the 1970's are less likely going forward. In addition the high price scenario in the EU Roadmap described in the Methodology includes price shocks but still averages out at a 2.75 % annual price increase. Thus annual price increases > 3 % per can be assumed not likely to occur over the scenario period for any sustained length of time. Whether price increases of even 3 % per annum, for example in the form of escalating carbon taxes, are politically feasible is an issue that requires further research[3]. Legislated price increases e.g. carbon taxes, are obviously politically difficult to impose to any extent that can be equated with significant long-term increases in prices. The possibility of increased incidence of fuel poverty with rising energy prices would also suggest political caution (Liddell, 2012). This suggests that the high price scenario described in this paper shows an upper limit on price effect (3 % per annum). The implication of this is that the effect of rising prices in the residential sector is significant but not sufficient and that to meet relevant EU goals more non-prices policy measures are necessary.

The EU Roadmap (2011a) states that as long as sufficiently stringent carbon price incentives across sectors can be put in place, the emission reductions of 80 % to be accomplished by 2050 will be enabled mostly by changes in technology plus "a modest contribution" from price-induced changes in behaviour. With regard to (direct) emissions from the residential sector the specific goal of the EU Roadmap in 2050 is a reduction by 90% although the key enabling measures proposed for this sector are new financing models. Thus price-induced changes in technology are not considered to be paramount in the residential sector. To meet the goal outlined in the EU Roadmap for the residential sector then, the price effects shown in the present paper would have to be combined with financial instruments that lead to changes in technology e.g. the deployment of more carbon-neutral heating systems and retrofitting. This would be equivalent of increasing the effect of non-price policy measures (represented in the model by the time trend). In a similar work examining the energy efficiency gap for space heating the authors of this paper show that the annual rate of technical development, legislation and regulations applied would need to be doubled to realise the techno-economic savings potential for the case of the Swedish Residential Sector by 2030 (Ó Broin et al, 2013b). In a bottom-up study the authors also show that a combination of minimum efficiency construction standards, improved conversion efficiency standards for final energy to useful energy, and a ≥2% annual improvement in end-use efficiency applied at the useful energy level can halve EU primary energy demand in the building sector to 2050 (Ó Broin et al, 2013c). This gives an indication of the need for an increase in non-prices policy measures that are necessary to meet EU goals.

The results shown in Figure 1 indicate that the average unit consumption for each country is a long way from the passive standard by 2050. The passive standard for dwellings is not an EU goal in itself, and it has not yet been determined what are desirable mix of pricing mechanisms, retrofitting,

[3] The forthcoming revision of the EU Energy Taxation Directive (Inforce Europe, 2011) may contain contemporary views on this issue.

renewable and efficient heating systems and supply-side efficiency that will be applied towards decarbonising the EU residential sector. Although the EU Roadmap (2011) describes decarbonisation scenarios where there is gradual replacement of the housing stock with passive housing after 2040, with an annual stock replacement rate (ratio of annual demolition to the size of existing stock) of only 0.07% (Enper-Tebuc, 2003), it would take more than 1000 years for the housing stock to be replaced by new houses of passive standard. Rather than replacing the existing residential building stock with Passive houses, Ürge-Vorsatz et al (2011) suggest retrofitting the existing residential building stock to the passive standard at a rate of 1.3% per annum to 2019, increasing through learning and up-skilling to 3% per annum in the period from 2020 to 2050. The results obtained in the present work show that such an effort would require far more than price mechanisms to succeed and reemphasise the limits of the price effect.

CONCLUSION

It is concluded that in a scenario with energy price increases of 3% per year, unit consumption falls to between 95 kWh/m^2/year and 65 kWh/m^2/year by 2050 across the four countries examined. This may be a satisfactory outcome if policy makers conclude that the most sustainable solution is to retain and develop a substantial renewable electricity and heat infrastructure to supply the remaining space and water heat demand. If on the other hand the goal of policy makers is that a large proportion of the residential building stock will be passively heated by 2050, then additional policy measures will be needed to reduce unit consumption further. As price increases of > 3 % per annum are unlikely, price rises will need to be combined with increased implementation of non-price policies to reduce unit consumption closer to the passive standard of 15 kWh/m^2/year.

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