Households under carbon constraint : A TIMES model of French Residential and Transports sectors

The direct domestic energy consumption in the residential and the transports sectors represent about 45% of the total CO_2 emissions in France in 2005 [1]. As a member of the EU, France is concerned to achieve the global 20% reduction of CO2 emissions in 2020 and the French government has inscribed a 75% reduction of CO2 emissions by 2050 in its energy orientation law in 2005. How would such an overall carbon constraint be declined over the households ? Describing **household energy behaviour** in long-term energy planning models such as **TIMES** is crucial to answer correctly to the question.

Two major criticisms are generally made against prospective studies led with TIMES models. As TIMES lies on an optimization system, a **"winner takes all"** issue may occur when the final energy demand is not enough disaggregated. The use of a single "mean representative" household leads the best suited technology for this mean household to take up the entire market share and to ignore the other technologies[1]. Moreover, in TIMES we consider the optimization of the global energy system and this can lead to the well-known **"energy efficiency gap"** issue [2]. Studies with TIMES generally point out the existence of profitable[2] energy efficiency measures that are not adopted in fact by households. The explanation is that these measures are found to be profitable under the assumption of low discount rates that generally lie between 4 and 8%, which is coherent with state's policies but very far from realistic household's behaviour. Indeed according to famous economic results, household investment behaviour is more consistent with **high apparent discount rates**[3] that lie between 15 and 20% [3,4]. These misconceptions may weaken the results obtained with TIMES model for prospective purposes and may suggest inefficient or at least inappropriate politics.

We then adopt a **detailed representation** of the final energy demand based on segments of households. We also include in our approach **behavioural variables** in order to describe the optimal technological choices from the household point of view.

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[1] Modellers are thus generally forced to moderate the diffusion with exogenous constraints on the penetration rate but loose the interest of the optimization system.

[2] i.e : from the collective welfare point of view

[3] The term "apparent" discount rate is related to the fact that the household act as if he had a personal discount rate - a time-preference that leads to a demanded profitability - of 15-20%. In fact this discount rate encapsulate the fact that there are a lot of market barriers to energy efficiency.

In 2009 we have launched a paper survey among 2000 French households and thanks to the collected data we have been able to draw a classification of households. These segments of households are established in regard to **constrained energy consumption** in residential and transports sectors and are based on **socio-demographic attributes** like income, age, house occupation status or geographical localisation. In this survey we have collected technical attributes such as the level of insulation of the housing, the different kinds of technologies owned by the households for space-heating, transportation or else hot sanitary water. But we have also collected behavioural attributes such as temperature of the house during winter, distances travelled and transport's means used, declarative discount rates and main criterion used to invest in new technologies.
We detail three main advantages provided by a detailed description of households to represent energy demand.

First, we are able to differentiate the **access** of the households **to the technologies** which leads to different baskets of available substitutes. For instance a rural household has a limited access to transport networks and a tenant household would not be able to insulate his home.

Second, we can describe more precisely the base-year situation for each household category in term of equipment and consumption level. So the **energy savings potential** and the **relative attractiveness of the new technologies** are estimated more accurately. For instance the attractiveness of a heat pump compared to an electric convector deeply depends on the initial level of heating consumption. That is to say the insulation level of the house, the efficiency of the old equipment and the room temperature demanded by the household. We are then able to better design technology **diffusion curves** thanks to the heterogeneity of the profitability of the new technology among households.

Third and not least, this description enables to differentiate the behaviour of the different segments of households. In fact the **way of life** of the households which implies a certain way both to **invest in new equipments** and to **restrain in the energy consumption** [5] deeply depends on the socio-demographic attributes that have been used to establish the classification. For instance the income would play an important role : poor people would face capital constraints to invest in new efficient technologies and are then forced to restrain

themselves in order to save energy whereas we observe the opposite arbitration for rich people [6].

In the TIMES long-term energy planning model, the way to invest in new technologies is modelled by a specific discount rate. And the value of these discount rates may be strongly influenced by income, age or ownership status and depend on the type of technology. The paper survey helps us to provide specific values of discount rates for each kind of technology and each type of households. So that we are able to model differentiated investment behaviour.

Finally, thanks to this detailed description we are able to model the best suited technologies and the timing of investments in optimal technologies for each type of households. The model also provides information about *arbitrations* made by the households between investments in housing's technologies and transportation's technologies as we consider capital constraints.

We can then highlight the impact of a **carbon tax** on the different types of households or the effect of a **global carbon constraint** on residential and transports sectors and discuss of potential **inequalities** between households in the sharing of the burden.

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