CHEETAH – Changing Energy Efficiency Technology Adoption in Households

Final report

The CHEETAH project consortium

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CHEETAH

Project partners

The project *Changing Energy Efficiency Technology Adoption in Households* (CHEETAH) is a three-year Horizon 2020 research project running from 2016 to 2019. It has the following project partners:

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The CHEETAH project at a glance

The CHEETAH project aims to provide evidence-based insights in the decision-making process of households, related to energy efficiency measures and the underlying reasoning of these residential decision makers. The project further models the impacts on energy demand and the economy if policies are adapted to those insights. This is done on three levels:

1. On the micro level, the project empirically analyses factors influencing individual decision-making and the response of households to different policy instruments based on demographically representative surveys, which are conducted in eight EU member states.
2. On the meso level, the project analyses the impact of the households' decision criteria and several different policy instruments on the diffusion of energy efficiency technologies. This is done using the modelling tools FORECAST for the appliance sector, Invert/EE-Lab for the heating and cooling sector and the EM-Lab Consumer model, which covers both sectors. This analysis has been conducted for the eight EU member state countries covered by the survey, as well as the remaining 20 Member States (FORECAST and Invert/EE-Lab only) based on clustering of countries into groups with similar household energy consumption and income structure.
3. On the macro level, the CHEETAH project explores the macroeconomic effects of policy instruments addressing energy efficiency until 2030 and 2040 on indicators such as GDP growth, employment and exports. For this analysis, we applied the ASTRA model.

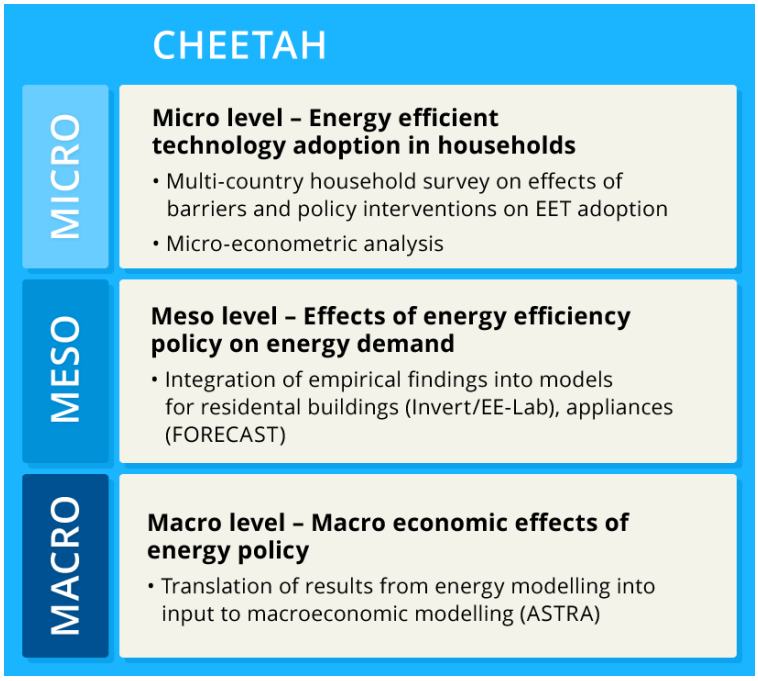

Figure 1. The project's three levels of analysis – at a glance

The key results and policy implications on the three levels of analysis are briefly summarised below.

At the **micro level – individual households –** the policy implications are derived from the empirically observed decision making behaviour in demographically representative Discrete Choice Experiments (DCEs) in eight EU countries. The survey results allow the research team to derive overarching policy implications such as the importance of building

trust, the importance of transparent policy-making and an open discourse to foster understanding of direct and indirect long-term costs and benefits. Furthermore, the importance of enabling consumers to make informed decisions by increasing energy literacy as well as by providing relevant information (such as monetary savings) in an accessible manner became apparent. The survey results also emphasize that the CHEETAH approach of a multi-country analysis which accounts for different types of households is crucial in order to get a more detailed understanding of the adoption-behaviour of energy efficient appliances as well as the acceptability of energy efficiency policies. This in turn provides the basis for policy design that is more fit-to-task and efficient and avoids unintended side-effects.

At the **meso-level – the energy system –** the modelling results have to be distinguished between electrical appliances and buildings. For appliances, the results show that the current design of the EU Ecodesign and Labelling requirements delivers distinct energy savings by the year 2030. These savings can be boosted further by tightening the mandatory minimum energy performance requirements associated with the Ecodesign Directive. However, this induces substantial additional costs to households, at least in the short term. Rebates, disbursed particularly to low-income households, can mitigate some of the financial burden imposed through stricter regulation. In addition, policy effectiveness depends on the degree of compliance with ecodesign requirements in retail sales. For buildings, the modelling results clearly indicate that significant energy savings in the residential heating sector can be achieved only through ambitious building refurbishment. The adoption of thermostats/heat control devices can help reduce the energy consumption, with the projected impact however being modest. It should be taken into account that thermostat adoption lowers the annual energy bill, which then reduces the profitability of later, more substantial, refurbishment measures. In this context, the modelling results indicate that particularly low-income households may not be able to raise the investments required for deep refurbishments. This may lead to a significant drop in refurbishment rates in the long term. Thus, enhanced financial support for low income households across member states should be taken into consideration. Furthermore, in order to trigger refurbishment activities in rented apartment buildings, the landlord-tenant's dilemma still needs to be addressed.

At the **macro-level – the economy as a whole –** the CHEETAH results show that the investments in residential energy efficiency are projected to have at least modest positive economic impacts for the EU. A combination of energy savings and rebates is able to compensate for negative consumption impulses resulting from investment expenditures. This leads to a slightly positive effect on overall consumption in the EU. Different income groups are affected in slightly different ways by the energy efficiency measures considered and the ensuing macroeconomic dynamics. However, it appears unnecessary to introduce allocative measures on top of (partially) targeted rebates, since macroeconomic dynamics counteract regressive tendencies. But it is very important to look at the long-term dynamic impacts that would arise after investments are paid off. And last but not least energy efficiency policies also make a contribution to the new European Green Deal by significantly reducing residential GHG emissions without negative impacts on the labour market. Due to the lack of regressive effects on the macroeconomic level, beyond rebates there is no need for additional financial packages, such as envisioned by the Just Transition Fund.

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1 The CHEETAH conceptual approach

Methodologically, the project follows a three-step approach, consisting of a very large household/consumer survey (micro-level), followed by bottom-up modelling on the meso- and macro-levels. The survey was conducted in the form of discrete choice experiments (DCEs) and covered 18,000 subjects in eight Member States deemed to be representative for the EU as a whole[1].For the modelling at the meso-level, both an agent-based model (EMLab-Consumer) as well as two energy demand models covering appliances (FORECAST) and buildings (Invert/EE-lab) were applied. For the modelling at the macro-level, the macro-economic model ASTRA was used.

However, for a sound foundation of the empirical and modelling work of CHEETAH, this approach was preceded by a literature review which aimed at identifying the technological and behavioural factors and policy instruments to be included in the survey and subsequent modelling (**Figure 1**). With regard to the conceptual design of the survey, a review of recent literature on household adoption of energy-efficient technologies, in particular their response to policies, was carried out. In addition, a review of the literature on policy responses and policy acceptance and an overview of the energy efficiency policies that are currently implemented in the EU and its Member States was conducted. Concerning the modelling, the complementarities between energy demand models and agent-based models (ABM) in their ability to simulate policy response in household's energy efficient technology adoption were explored within the scope of the pre-analysis.

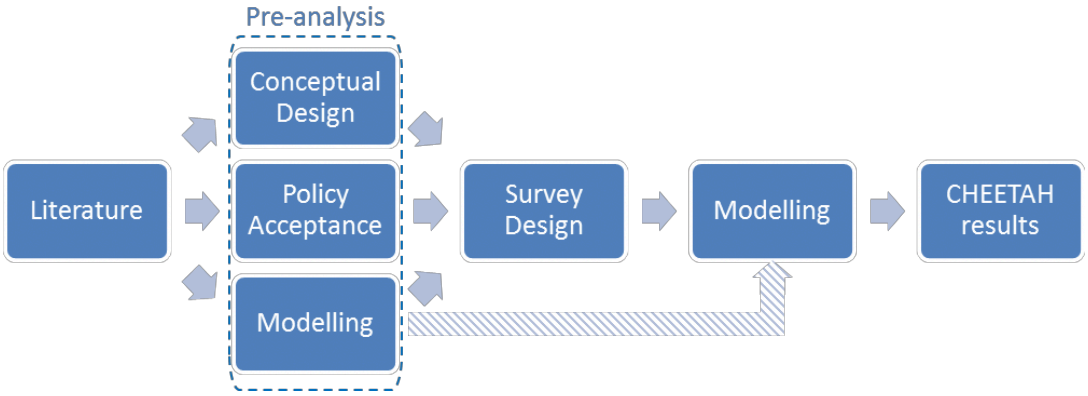

Figure 2. Overall conceptual approach of the CHEETAH project

The following conclusions could be drawn from the literature review for the design of the survey and the modelling:

- According to literature, financial aspects are a key factor for investment decisions in private households. The profitability of energy efficiency measures and the occurrence of rebound effects[2] are the most prominent topics of the bibliometric analysis. Therefore, costs and benefits should also be reflected in the choice experiments. Usually, private costs are expressed by calculating attributes like the implicit price, willingness to pay or operating cost, and the benefits are displayed by energy (cost) savings and the payback period.
- Analysing the connection between policy acceptance and household clusters, a correlation between age, ownership status, income and education is detected by the empirical findings. The influence of household size and social norms and values is ambiguous or underexposed. What can be substantiated by literature so far is, that a

[1] UK was part of the survey and the analysis since it was still an EU member during the full duration of the CHEETAH project.

[2] The direct rebound effect means that energy cost savings due to energy efficiency improvements may lead to additional energy consumption in other areas.

general trust in the system stimulates the belief that certain policy measures are effective and fair.

- Different energy efficiency technologies were identified ranging from building, heating, lighting and white goods. In the BRISKEE project that preceded CHEETAH, an almost equally large survey in the same eight countries focused on four white goods appliances with mostly identical households' purchase criteria. Therefore, technologies investigated in the CHEETAH survey were chosen to reflect a broader range of household appliances and building technologies.
- The review also showed that energy demand models that inform and provide the basis for policy making usually include a representation of household investment decisions which can be influenced by policies. The choice experiments in CHEETAH should therefore provide input for the modelling by generating empirical data on how households are influenced by policies and how they perceive different attributes of investment options.
- The overview of existing energy efficiency policies pointed out that regulations, transparency and information as well as incentives and financing are the kind of policies that directly influence the decision-making process in private households. These policies therefore build the core of CHEETAH's empirical work.

Table 1 summarizes the selection of policies that were chosen for the further empirical work in CHEETAH, based on the pre-analysis. It also provides the link between the policy instruments, the discrete choice experiments (DCEs) and the agent-based modelling (ABM) and energy demand models. The table further highlights a differentiation according to the technologies applied in the DCEs and in the models.

Table 1. Policy instruments covered by the DCEs and the models

Policy Instrument	Technology	DCEs	Models
Appliances			
Labelling	Refrigerator	X	X
Information (Energy Literacy)	Refrigerator	X	-
Rebate	Refrigerator	X	X
Buildings			
Information (Recommendation)	Smart Thermostat	X	X
Rebate	Smart Thermostat	X	X
Rebate	Heating System	X	X
Market-based instruments (MBI)	Heating System	X	-
Policy Acceptability (trust, fairness, policy type)	Technology generic	X	-

An overview of the entire conceptual approach followed in the CHEETAH project is given in **Figure 3**.

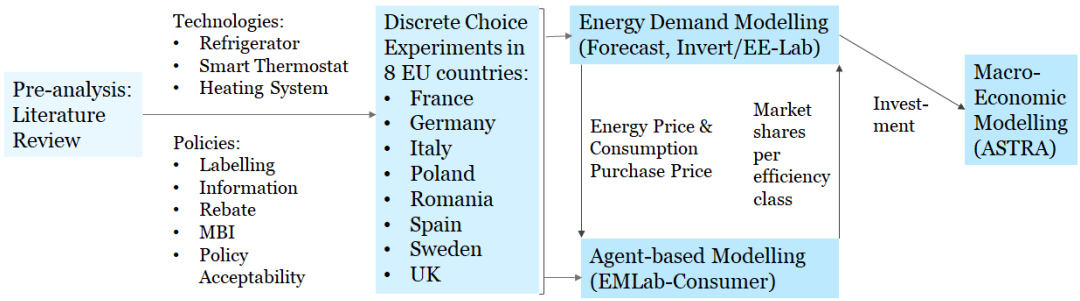

Figure 3. Concept for the survey design and the modelling approach derived from the pre-analysis

2 Main CHEETAH results and policy conclusions

2.1 Micro-level analysis: household level implications

Employing demographically representative discrete choice experiments (DCEs) in eight EU countries, allows for various policy implications. In the following, the derived policy implications are described with respect to the three technologies tested, refrigerators, thermostats and heating systems as well as for the DCEs on policy acceptability. Where applicable an outlook on wider implications is sketched.

As described above the DCE on refrigerator purchase decisions allowed participant responses to the EU energy labelling scheme and to rebates for A+++-labelled refrigerators to vary by income and energy literacy. This allows for various policy implications.

Overall, we find that respondents in all countries typically prefer A+++-labelled refrigerators to refrigerators with lower energy classes. Thus, the EU energy label appears to effectively signal additional benefits of these appliances to the consumer such as energy-cost savings. Yet, low energy literacy was found to substantially lower the willingness to pay (WTP) for A+++-labelled refrigerators in half the countries included in this study (France, Germany, Poland and Sweden). This finding holds for low- and high-income households. In addition, the findings suggest that rebates for A+++-labelled refrigerators (the highest efficiency class) are an effective measure to boost the adoption of A+++-labelled refrigerators in all countries. The results further suggest, that on average, rebates are most effective for high income household in Italy, Poland and Romania, and low literacy households in Germany and Poland (looking at the difference between A+++ sub and A+++0). In some countries (Italy, Romania, Spain), the positive effect of rebates is stronger for high-income households than for low-income households. This finding tends to hold for low and high levels of energy literacy. Thus, in these countries, providing a rebate for energy-efficient refrigerators may be regressive, and thus have unwanted distributional effects. In this case, rebates could be offered to low-income households only. To keep transaction costs low (e.g., for providing proof of income), such schemes could be linked to household eligibility for existing social-security support. Restricting rebates for A+++--labelled refrigerators to low-income households would also be expected to limit free riding.

In countries such as the UK, where consumers may perceive rebates and subsidies as signalling low quality, rebate and subsidy schemes could be complemented by customer ratings or by reports from organizations providing credible product ratings and reviews such as Consumer Reports.

The findings on energy literacy suggest that labelling schemes are more effective for customers with a higher energy literacy. Thus, raising the level of energy literacy via education and information programs (e.g., brochures, online or on-site courses) may be an effective means. Ideally, such programs would be targeted at particular socio-economic groups. Specifically, the results from running probit regressions on the factors related to energy literacy imply that such programs should be targeted at women in Poland and Romania, at younger people in Italy and Sweden, or at individuals with low formal education in France and Spain. For some countries, notably Poland, Spain and Sweden, focussing such programs on particular regions also promises to be effective. In addition, information and tools on how to calculate energy cost savings for the various appliances may be provided at the point of sale, i.e., either in the store or through an internet platform (see also Blasch et al., 2018[3]).

Finally, the results of the choice experiments for refrigerators (particularly concerning energy literacy) lead us to contemplate that if information on the energy label was more informative, energy literacy may not play as big a role. Arguably, providing energy costs (in €) rather than

[3] Blasch, J., Filippini, M., Kumar, N. (2018). Boundedly rational consumers, energy and investment literacy, and the display of information on household appliances. *Resource and Energy Economics*.

energy use (in kWh) would help customers to identify the refrigerator with the lowest costs (e.g., lowest total costs of ownership).

In all countries the results of the DCE for thermostats show that if the recommendation for a certain appliance is provided by experts it has a more positive effect on the adoption decision than if the recommendation is provided by a friend (only). These results are particularly strong for elder homeowners in Italy, Spain and Poland. The results offers some leverage for recommendations and suggests that thorough, independent and transparent information provision might increase the adoption likelihood (e.g. through decreasing doubt on the actual savings). In combination with the findings on energy literacy from the DCE on refrigerators it is suggested that providing these information as accessible as possible, e.g. in terms of potential monetary savings rather than energy savings, would be beneficial for their adoption. Furthermore, recommendations provided by the provider have positive effects in all countries except for Poland and low-income households in Romania (negative effects) and Sweden (no significant effect). Being particularly positive for elder homeowners in Spain and Italy. Therefore, it would be worth exploring which incentives could be set to providers to facilitate the adoption of thermostats by their clients.

The results of the DCE for thermostats for Rumania suggest that a subsidy for efficient appliances has an overall positive effect for their adoption. Here, one additional Euro of subsidy stirs a propensity to adopt a certain technology that goes beyond the mere monetary value. In all other countries subsidies do not have a positive effect on adoption decision. Particularly the results suggest that subsidies for efficient thermostats in Germany, UK and Spain as well as for low-income households in Sweden do not stir positive effects, since they are valued less than their actual monetary value. Overall the results from the DCE for thermostats suggest that providing information on savings and recommending certain energy efficient appliances through experts and providers is more beneficial than providing subsidies. This might also be due to the fact that the savings for thermostats are more complex and less directly accessible to households than savings from other appliances.

The DCEs for heating systems, which were conducted in Poland, Sweden and UK, suggest positive effects of subsidies which are provided by private actors in all three countries, while only in Poland a positive effect of subsidies provided by a public actor is observed. Therefore, it seems to be most beneficial to provide incentives to private actors which can be forwarded to technology adopters rather than providing financial schemes through public actors. Low-income households in the UK value subsidies less than high-income households, regardless of whether they are provided by public or by private actors. This suggests that subsidies in UK, like subsidies for refrigerators for some countries, would be regressive in nature. Therefore, it should be considered to provide subsidies for heating systems in UK only to low-income households in order to avoid increased free-rider effects. Aside from subsides, the reduction of heating costs, an increase in warranty time and a shortened installing period are beneficial for the installation of energy efficient heating systems in all three countries. Providing upfront and accessible information on these items might therefore be beneficial for adoption.

The detailed study of policy acceptability allows for conclusions concerning the type of policies that are more likely to be accepted and concerning preconditions (such as trust) that support the acceptability of energy efficiency policies in general. Overall, citizen support for and resistance to different types of policies can be found, and also variation in preferences amongst different countries and groups of citizens. In particular, our research highlights that energy efficiency policies are more acceptable when they are particularly effective (i.e., ambitious in reducing energy consumption and imports) while also incurring minimal costs on, or coercion of, citizens. Unfortunately, these criteria may be difficult to reconcile as the most effective policies are likely to include at least some degree of 'push' or coercion that limit consumer choices in respect of the most energy intensive choices. This may suggest a need to involve the public in more deliberative debate about the inevitable trade-offs involved with achieving a sustainable energy transition. As for example by spelling out that addressing climate change and energy security might incur costs in terms of higher bills and/or reduced consumer choices but potentially reduce costs for adapting to climate change or dealing with energy disruption/shortages. Such deliberative citizen engagement might also help foster a

sense of procedural justice in, and thus greater support for, policies developed through this participatory process.

At the same time, the results show that those who trust government more, who have benefited directly from energy efficiency policies in the past, and have higher green identity, are generally more supportive of energy efficiency policies (albeit with some cross-national variation). These findings point to where policy-makers might focus in building support for future energy efficiency measures, for example, by introducing financial support measures in advance of more coercive or costly measures or by designing informational measures that remind people of any benefits they have already experienced from energy efficiency policies. In addition, building trust in government would appear to be an important pre-condition for public support for policies, and therefore should be a focus of efforts (e.g., through more transparent and participatory policy-making). Environmental education might also serve to increase green identity and values amongst the public, which may also lead to more support for energy efficiency policies. Finally, since public support in some countries, like the UK, appears to be higher than elsewhere, and in light of cross-national variation in predictors of policy support, this indicates that policies need to be established with cultural or national differences in mind.

Summarizing, the result from the micro-level analysis conducted in the survey allowed to derive overarching policy implications such as the importance of building trust, the importance of transparent policy-making and an open discourse to foster understanding of direct and indirect long-term costs and benefits. The results also emphasize the importance of enabling consumers to make informed decisions by increasing energy literacy as well as by providing relevant information (such as monetary savings) in a more accessible manner. While the results show that certain policies will probably have no effect in a certain area (and thus do neither harm nor good), other polices (like rebates for refrigerators in Italy, Romania and Spain) seem to be regressive in nature, and are thus likely to increase freeriding. The results therefore emphasize that the here taken approach of a multi-country analysis which accounts for different types of households is crucial in order to get a more detailed understanding of the adoption behaviour of energy efficient appliances as well as the acceptability of energy efficiency policies. This in turn allows to design policies in a more fitting and efficient manner, avoiding unintended side effects.

2.2 Meso-level analysis: energy demand level implications

2.2.1 Buildings

At the meso-level, the building sector was analyzed through the energy demand model Invert/EE-Lab.

The main policies and heating technologies that are studied within the buildings scenarios are:

- rebates for (intelligent) smart thermostats
- rebates for the efficient heating systems
- a policy package combining these policies with a specific focus on vulnerable agent groups such as low-income households, households with elderly people, or large households.

All results are calculated against a baseline scenario, which reflects the current policies for buildings.

Our results clearly indicate that significant energy savings in the residential heating sector can be achieved only by insulation of buildings. The installation of efficient heat supply systems and/or heat control devices help to reduce the energy consumption, but the impact is modest – at least in countries where the energy performance of the buildings is not far below the EU-28 average. Therefore, the strong promotion of heat control devices without additional measures to invest in deeper refurbishment can even be a double-edged sword

leading to unintended effects later on. By investing in such devices, households reduce the annual energy bill, which then reduces the profitability of later, more substantial refurbishment measures. In addition, it partly satisfies the mental accounting behaviour of humans. By investing in some low-hanging energy efficiency measure, the urge to further reduce the energy consumption can be reduced significantly (see Seebauer, 2018[4]).

The results furthermore indicate that comprehensive energy savings require normative instruments and cannot be achieved easily with financial policies or soft measures such as increased information campaigns[5]. This is supported by the survey results on policy acceptance, which clearly show that measures building on coercions are less accepted.

Our results also show, that the financial investment needs for decarbonizing the residential heating sector are substantial. Especially for low income households, it is in question whether or not these households will be able to raise the required investments. Although our model results do not indicate a strong correlation of the household income and the renovation activities within the considered time horizon, this has to be interpreted considering the underlying assumption that low income households are able to access the capital market under the same conditions as other income groups. If this assumption is violated and low income households can raise capital only under heavily adverse conditions, refurbishment rates for low income households will drop significantly.

Therefore we suggest to focus with the (additional) financial support on low income households and increase measures that allow such households to efficiently access capital market. Our results indicate that the overall savings may not decrease substantially, if the existing financial support is shifted more towards low income households. Also, based on the survey results on policy acceptance, we don't expect that such a policy scheme doesn't conflict too much with the fairness values of households.

Furthermore, in order to trigger refurbishment activities in rented apartment buildings, landlord-tenant's dilemma needs to be addressed (Ástmarsson, 2013[6]). Our scenarios are derived under the presumption that building owners are able to raise up to 60% of the additional costs – compared to the option with the lowest investment costs – from tenants by raising the rent. In cases were the rent already includes heating (e.g. common in Sweden) the landlord will financially profit from lower energy expenditures for heating, the same is true if energy savings obligations are in place. If these conditions are not in place and the apartments are rented out on net rent conditions that do not include heating, landlords would need to be able to increase the rent to get some return on their profit. Two options to increase the rent can be considered. However, national regulation and established practices may complicate the picture further.

The first option, is an increased rent when a new rental agreement are signed. This includes the case when tenants change apartments as well as the case of renewal of fixed-term contracts. In those cases, landlords can increase their rent already under current law in (most) regions and for most building types[7] and adopt the rent tailored to the specific housing market. This mechanism, however has only a considerable effect if the housing market is dynamic and fixed-term contracts with rather short durations are frequent.

The second option of raising the rent, would be by allowing landlords to adjust the rent within the running period of existing rental agreements in order to cover investments taken that lower the running costs for tenants. This measure is heavily debated, with arguments on both sides. Currently it is possible in Germany where it is called "Modernisierungsumlage". After being introduced in 1974, landlords were able to increase the rent by 14% (which was 2.5% above the credit rates for 10-year mortgages Scheidacker, 2018[8]) and has been decreased

[4] Seebauer, S. (2018). The psychology of rebound effects: Explaining energy efficiency rebound behaviours with electric vehicles and building insulation in Austria. Energy Research & Social Science. Volume 46, Pages 311-320.
[5] Even though the effect of non-monetary, non-binding mechanism remains unclear (Liebe, U.; Gewinner, J.; Diekmann, A. (2018). What is missing in research on non-monetary incentives in the household energy sector? Energy Policy, Volume 123, 180-183)
[6] Ástmarsson, B.; Jensen, P.A.; Maslesa, E. (2013). Sustainable renovation of residential buildings and the landlord/tenant dilemma. Energy Policy, 63, 355-362.
[7] Some restrictions are given in different countries and buildings types or regions, such as rent caps.
[8] Scheidacker, T. (2018). Sondierungspapier: Absenkung der Modernisierungsumlage. online: https://ikb-law.blog/2018/01/16/sondierungspapier-absenkung-der-modernisierungsumlage [last access: 2019-06-18]

later on to 11%. Since the credit rates dropped to 1-2% in the recent years, opponents argued that the rate was too high and didn't represent the actual costs of land lords. Subsequently, the annual share of investment costs that can be added to the rent in the course of refurbishment actions has been decreased in January 2019 to 8%. Without such an option to recover investment expenditures taken to modernize buildings (and in the lack of a refurbishment obligation), the renovation rate of buildings with predominantly rented apartments, drops to virtually zero, according to scenario runs using the applied model. If on the other side, this rate is set above the land lords actual cost, such it was the case in Germany, landlords have an incentive to overinvest since they can generate additional income from the increased rent.

2.2.2 Appliances

At the meso-level, the appliances were analysed through the energy demand model FORECAST Residential Appliances and the agent-based model EMLab-Consumer.

For cooling appliances (refrigerators and freezers), the EU energy demand is decreasing due to increased efficiency in appliances, which is the result of technical advancements and support by the current policy framework fostering energy efficiency. However, it is possible to further speed up the diffusion of energy efficient products as the results of the CHEETAH project show.

The main policies that are studied within the appliances scenarios are:

- more stringent ecodesign requirements (i.e., minimum energy performance standards, MEPS)
- rebates
- a policy package combining these two policies.

As for buildings, all scenario results are calculated against a baseline scenario, which reflects the current policies for appliances.

Setting more stringent ecodesign requirements is an interesting option, at least from the state perspective, since the implementation costs are very limited compared to the energy savings. In the energy demand model FORECAST it is the policy, which shows the highest effectiveness. However, for products which have already been regulated for long time and for which the low hanging fruits most likely have already been harvested – like cooling appliances - further energy savings cannot be realized with cost savings in all countries and for all consumers groups. More stringent ecodesign requirements trigger two challenges: First, a social challenge: stringent ecodesign requirements will lead to increased investment costs and might lead to increased total costs of ownership. Additionally, due to the heterogeneity of electricity prices and purchase price of very efficient appliances in the EU, the cost benefit is not met in many Member States. This is specially an issue with low income groups. Second, a legal challenge on the EU level: The Ecodesign Directive (2009/125/EU, see Article 15, §5 c) sets criteria regarding implementing measures " c) there shall be no significant negative impact on consumers in particular as regards the affordability and the life cycle". Setting more stringent ecodesign requirements would probably require a revision of Article 15 §5 c unless there would be a way to factor in learning curves and improved innovation speed on the side of the suppliers.

The studied rebates show effects, but the magnitude depends highly on the country and the target group. Generally, rebates that are directed only towards low-income households are more cost efficient than rebates directed to all households, particularly because free rider effects are decreased. However, from a state budget perspective, rebates are quite expensive. Implementing the survey results into the energy demand models leads to the insight that consumers do not necessarily take their decisions based on a cost analysis. This leads to the result that the effect of subsidies is not always as expected from economic considerations. For example, while the economic analysis showed that a rebate program would make an appliance from a high-energy efficiency class cost effective (compared to the current policy scenario), no systematic impact on customer preferences could be observed.

Usually, incentive programs are elaborated on the basis of barriers and economic analysis. The amount of the subsidy is then adjusted in order to make the intended technology cost effective compared to the technology usually purchased. However, these analyses might underestimate non-economic preferences of the consumers and their rationality or even lack of rationality.

Finally, the CHEETAH project showed evidence that rebates combined with (stricter) ecodesign requirements deliver good results in terms of adoption of EE technologies. They have the advantage over the mere rebate programs that they significantly reduce the costs from a state perspective. While in the combined policy package of ecodesign and rebate programs the saving of one kWh costs a maximum of 1.25€, the prices to save one kWh only through a rebate program are up to 10€. At the same time, the policy package has the advantage over the purely stricter implementation of ecodesign reuirements that from a consumer perspective the EE appliances are not more expensive. Contrary, they can even unburden low-income households, which might be particularly vulnerable to increased costs due to stricter energy performance requirements through ecodesign requirements.

The work done in the CHEETAH project highlights the need to elaborate policies in a new way. Consumer preferences are key in the adoption of EE technologies and can be gathered through DCE of which results can be integrated in the elaboration of energy efficiency policies. Especially for rebates, it is recommended to take into account the preferences of the target group to adjust the optimized level of subsidies, which will maximize the ratio policy effectiveness / cost of the policies, rather than simply assuming a purely economic decision-making process.

The agent-based model EMLab-Consumer has directly implemented the survey results, representing each survey respondent and their preferences as one agent in the model. The strength of this approach is that few additional assumptions have to be made about the preferences and behaviour of the agents. Hereby, households decide individually and each fridge has its own properties (such as energy label, size, price, warranty and the availability of subsidies). The options for fridges households are really able to consider – fitting in the household, being of sufficient size – could well limit the effects that rebates may have and may provide a real barrier for household adoption of efficient appliances. Furthermore, the set of fridges available in the market is very important. It is crucial for the customer, which appliances he or she sees available in the shops. This suggests the crucial importance of the standards being stringent and the particular importance of all policies that affect what shops have in store and to what conditions they offer it, ultimately affecting the options that consumer come across in the various shops. Furthermore, the EMLab-Consumer results capture some rebound effects: The energy efficiency gains from adoption of appliances with better energy labels are partly cancelled out by the preferences of consumers' shifting to fridges with larger volumes.

2.3 Macro-level analysis

For the analysis at the macro-level, the macroeconomic ASTRA model was used. Following the policy scenario approach at the meso-level, the following two scenarios were analysed at the macro-level:

- an individual policy instrument scenario (S1)
- a policy-package scenario (S2)

As at the meso-level, all results are calculated against a current policy scenario, which serves as a baseline.

The macroeconomic effects of the two analysed policy scenarios are rather small compared to the overall economy of the EU 28 (**Figure 4**). The small magnitude of effects is expectable since the sums of the impulses on the country level rarely surpass 0.5% of GDP. However, it could be shown that the investment in energy efficiency technologies and the associated energy savings can have moderate positive overall effects, such as reducing the reliance on energy imports and pointing towards structural shifts of the economy that does not have regressive effects.

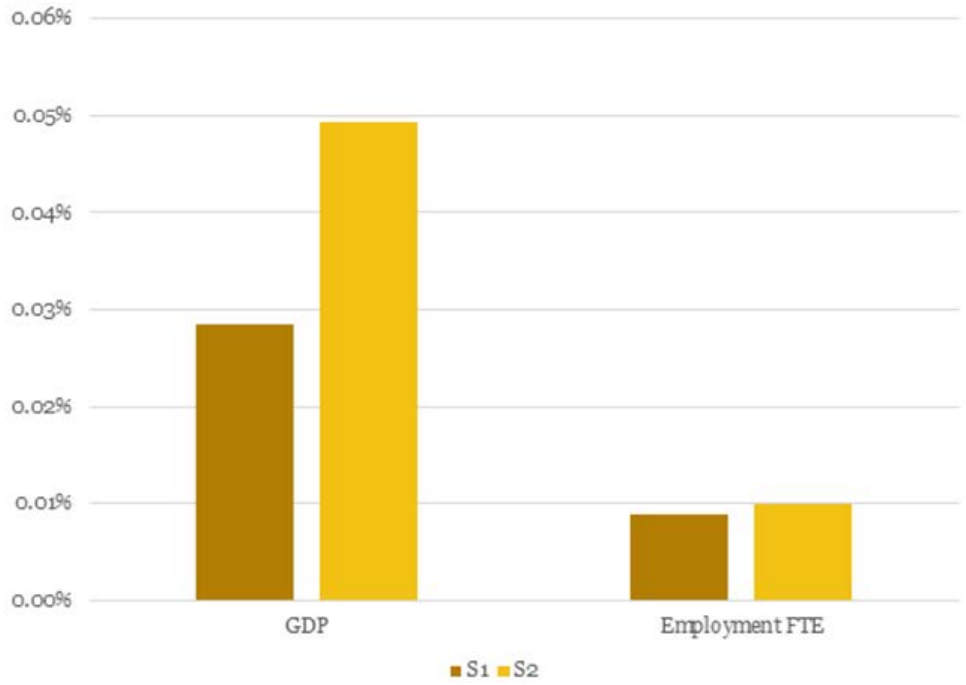

Figure 4. Relative yearly GDP and employment change (in full time equivalents, FTE) for EU 28 in 2030 for the individual policy instrument scenario (such as rebates only) (S1) and the policy-package scenario (S2)

These positive effects are mainly due to the combination of energy savings and rebates, which is able to compensate for aggregate negative consumption impulses (i.e., consumption other than energy) resulting from disposable income being directed towards investments rather than consumption. Different income groups are slightly differently affected by the energy efficiency measures considered and the ensuing macroeconomic dynamics. While the disposable income of all groups increases, the increase is slightly bigger for the lower quintiles than for the higher ones, which can be explained by higher rebates for the lower income groups and beneficial sectoral shifts resulting from the investment impulse. It therefore appears unnecessary to introduce allocative measures on top of (partially) targeted rebates, since macroeconomic dynamics counteract regressive tendencies.

On a sectoral level, it can be observed that manufacturing generally benefits from the investments in appliances and building technologies. The biggest accrue to the electronics sector. In contrast, the energy and minerals sectors (which also include fossil fuels) experience a small decline in value added and employment relative to the baseline scenario. The macroeconomic effects are also negative in some service sectors, due to the negative impulse on final consumption in the case of higher investment costs than energy savings.

Taken together, the macroeconomic impacts of the scenarios show characteristics of an investment process, which on the one hand strengthens manufacturing industries but comes at the cost of temporarily reduced aggregate consumption. At the same time, the fiscal position of households is strengthened through energy savings that extend beyond the investment period. It is therefore important to look at the long-term dynamic impacts that would arise after investments are paid off. The positive effects of energy costs reductions cannot fully be accounted for within the time framework chosen (i.e. up to 2030) because they keep accruing to households after the simulation period.

Energy efficiency policies also make a contribution to the new European Green Deal by significantly reducing residential GHG emissions without negative impacts on the labour market. Due to the lack of regressive effects on the macroeconomic level, beyond rebates there is no need for additional financial packages, such as envisioned by the Just Transition Fund.

3 Dissemination

The CHEETAH project followed a dissemination strategy, which was as comprehensive as possible given the strong research focus of the project. This strategy complemented the events and workshops (some of which were in the form of consultations with the research community). The activities served to assure a successful dissemination of the CHEETAH project outcomes and results to the targeted audience – researchers and those involved in creating and implementing energy efficiency policies in the EU residential sector.

The general communication tool with the broader public is the CHEETAH website www.briskee-cheetah.eu/cheetah (the web site features both the BRISKEE and the CHEETAH projects, reflecting the close relationship between the projects).

For broader communication, 9 mass mailings were made to eceee's large database of approx. 6,000 recipients. These were primarily focusing on CHEETAH events, but leading to project information through the event pages. In addition, CHEETAH events were featured in eceee's regular e-mails tens of times.

8 tweets and a couple of linked-in posts also featured CHEETAH by the end of the project period, but eceee will keep adding posts as more reports and articles are spun off from the project.

Furthermore all material produced within the project is available from the project website www.briskee-cheetah.eu/cheetah. This includes all reports and presentations as well as documentation from all workshops. In addition, the web site also ties CHEETAH well together with the BRISKEE project and presents reports and information from both projects and the links between them.

An infographic presenting CHEETAH was produced. It is available on the project web site.

4 Conclusions and Outlook

The CHEETAH project had the objectives of providing evidence-based input to energy efficiency policy-making by investigating the role of policy in household energy efficiency decision-making through a survey based empirical analysis on the micro-level and a modelling approach. The empirical data also served to improve the representation of decision-making processes of private households in the models at the meso-level.

The demographically representative Discrete Choice Experiments (DCEs) in eight EU countries delivered a huge database on the empirically observed decision making behaviour concerning energy efficiency investment and households' response to energy efficiency policies. The complete analysis of the survey data is available in several reports on the CHEETAH website: https://www.briskee-cheetah.eu/cheetah/. The raw data of the survey will also be made available as a data base on the project website continued use by third parties in the end of 2020 at the latest. Together with the raw data from the BRISKEE survey[9], they deliver a huge amount of empirical data on decision processes and policy response with regard to energy efficiency in private households in the EU. The BRISKEE-CHEETAH website will remain available at least for the next two years. Afterwards, it is planned to continue making the key publications and the two survey data bases available on the eceee website: https://www.eceee.org/.

By directly implementing the results from the Discrete Choice Experiments in the energy demand and ABM models, major enhancements could be made to the models. For example, previously *FORECAST* was not able to take differences of household characteristics into account, but assumed a uniform decision-making function for all household. While this provides satisfying results for the overall national and European scenarios, it does not provide any insights on how certain policies affect different household groups (such as low-income households). The enhanced modelling approach developed in CHEETAH therefore brought the modelling an important step closer to adequately modelling heterogeneity in households. These improvements in the models will also apply to future scenarios and further improve the validity of the models.

Last but not least, the CHEETAH results emphasize that the here taken approach of a multi-country analysis which accounts for different types of households is crucial in order to get a more detailed understanding of the adoption as well as the acceptability of energy efficiency policies in European households. This in turn allows to design policies in a more fitting and efficient manner, thereby also avoiding unintended side effects. These findings from CHEETAH will also be important in the longer term for the future design of energy efficiency policy in the EU and its Member States in the context of implementing the European Green Deal.

[9] https://www.briskee-cheetah.eu/library-and-reports/briskee-consumer-sruvey-raw-data-file/