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Yes, but no: Adoption and Rejection of Energy Efficiency Innovations

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Webinar Presenter

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Katie Hello, everyone. I'm Katie Contos and welcome to today's webinar which is hosted by the Clean Energy Solutions Center in partnership with Enerdata. Today's webinar is focused on Yes, but no: Adoption and Rejection of Energy Efficiency Innovations. Before we begin, I'll quickly go over some of the webinar features. For audio you have two options, you may either listen through your computer or over your telephone. If you choose to listen through your computer, please select the mic and speakers in the option audio pane. Doing so will eliminate the possibility of feedback and echo. If you choose to dial in by phone, please select the telephone option and a box on the right side will display the telephone number and audio pin you should use to dial in. If anyone's having technical difficulties with this webinar, you may contact the GoToWebinar's helpdesk at 888-259-3826 for assistance.

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Today's webinar agenda is centered around the presentation from our guest panelist Mark Olsthoorn, postdoctoral researcher at the Grenoble School of Management who has joined us to discuss energy efficiency barriers that firms and households face in Europe. Before we jump into the presentation I'll provide a quick overview of the Clean Energy Solutions Center. Then following Mark's presentation we'll have a question and answer session where he'll answer questions submitted by the audience. At the end of the webinar you'll automatically be prompted to fill out the brief survey as well so thank you in advance for taking a moment to respond.

The Solutions Center was launched in 2011 under the Clean Energy Ministerial. The Clean Energy Ministerial is a high level global forum to promote policies and programs that advance clean energy technologies to share lessons learned and best practices and to encourage the transition to a global clean energy economy. 24 countries in the European Commission are members contributing 90 per cent of clean energy investment and 75 per cent of global greenhouse gas emissions. This webinar is provided by the Clean Energy Solutions Center which focuses on helping government policymakers design and adopt policies and programs that support the deployment of clean energy technologies.

This is accomplished through the support in crafting and implementing policies relating to energy access, no-cost expert policy assistance and peer-to-peer learning and training tools such as this webinar. The Clean Energy Solutions Center co-sponsored by the governments of Australia, Sweden and United States with in-kind support from the government of Chile. The Solutions Center provides several clean energy policy programs and services including a team of over 60 global experts that can provide remote and in-person technical assistance to governments and government supported institutions, no cost for tool webinar trainings on a variety of clean energy topics, partnership building with development agencies and regional and global organizations to deliver support in an online library containing over 5500 clean energy policy related publications, tools, videos or other resources. Our primary audience is made up of energy policymakers and analysts from governments and technical organizations in all countries. But, we also strive to engage with private sector, NGO and civil societies.

The Solutions Center is an international initiative that works with more than 35 international partners across a suite of different programs. Several of the partners are listed above include research organizations like IRENA and IEA and programs like SEforALL, regional focus entities such as ECOWAS Center for Renewable Energy and Energy Efficiency. A marquee features that the Solutions Center provides is a no-cost expert policy assistance known as Ask an Expert. The Ask an Expert service matches policymakers with more than 60 global experts selected as authoritative leaders on specific leaders on specific clean energy finance and policy topics, for example in the area of energy efficiency we are very pleased to have Dave Carey, Principal Harcourt Brown & Carey serving as one of our experts.

If you have a need for policy assistance in energy efficiency or any other clean energy sector, we encourage you to use this valuable service. Again, this assistance is provided free of charge. If you have any questions for our experts, please submit it to our online simple form at cleanenergysolutions.org/expert. We also invite you to spread the word about this service to those in your networks and organizations.

Now I'd like to provide a brief introduction for our panelist today. Mark Olsthoorn, who is a postdoctoral researcher with a Ph.D. in business administration from Grenoble EM and a Master of Science in aerospace engineering from Delft University of Technology. His research interests include adoption of energy efficiency and load management techniques. And. with that brief introduction, I'd like to welcome Mark to the webinar.

Mark Yes, hello. My microphone is on I think.

Katie Yup, you sound wonderful, Mark. Welcome.

Mark And I will put on my screen.

Katie Wonderful, thank you so much.

Mark Okay. Yes, hello, everyone. And thank you, Katie for the introduction. And, thank you all for tuning in today. I'd also like to thank the Clean Energy Center and Enerdata for the opportunity to talk about energy efficiency with you. Before I start my presentation though I first want to say a few words about the school where I work. Here you see our school, Grenoble Ecole de Management. It's a French business school, from Grenoble which we say is the capital of the French Alps. You can see it on the map in the southeast of France. And the school was created in 1984, 34 years ago. And since then the school has grown to an internationally recognized business school. We now have about 8000 students who come to us from all continents for our leadership in technology and innovation.

In the school we have eight research teams, one of which studies energy management and that is the team that I belong to. Our team provides expertise on energy transition management, management of technologies and of strategic implication for business and policy. Our approach is cross-disciplinary. We combine quantitative research and marketing and economics and use econometric analysis and field experiments and qualitative research on business model innovation, relying on interviews and case studies. And our team is very international. We are of course active in writing scientific papers in European research projects. We also have a specialized masters in energy marketing and management and extension activities are very important to us.

We are in the process of developing a chair to develop practical knowledge for managing the energy transition and to do that in collaboration with stakeholders. So, if you are interested in collaborating with us, please write me an email or contact my colleague Carine Sebi. You can find our contact details at the end of this presentation. They'll be shown on a slide. Later on YouTube you can scroll back to find them or on Google of course. Now that said, let's get to business.

Yes, but no. The title will become clear in a few minutes, but the subtitle can give you a hint. It is about adoption and rejection of energy efficiency measures. This webinar will have four parts. First, I will introduce the general concepts of what is called the energy efficiency gap and the energy efficiency paradox. Then I will discuss two empirical examples from my own work. One is about finding explanations for adoption and rejection of energy efficiency measures and the second one looks at the effectiveness of a policy instrument to promote adoption. In this case the instrument is a subsidy. And finally, I will conclude with a brief macro level review of the progress made and to answer the question, are we closing the gap.

But let us first go back to the 1970s. Here you see a man paint spraying a sign saying, sorry, there's no gas. We're back in the middle of the oil crisis in the 1970s. It's these crises that made it felt how central and reliable a supply of energy is to our way of life. It showed that cheap abundant energy cannot be taken for granted. And in reaction to those crises, the U.S. government started championing energy efficiency as a multi etched sword, a solution to many problems. It went so far as to equate energy conservation to patriotism and said that each gallon of oil saved was a new form of production. This is just to show that energy efficiency emerged as a topic of political and academic interest in the 1970s launched the oil crises.

Several scholars supported the notion of energy efficiency as a win-win solution with huge unused potential. Here you have a quote renowned energy analyst Daniel Yergin who was at Harvard at that time. And he estimated that the U.S. could consume 30 to 40 per cent less energy and still enjoy the same or an even higher standard of living. And he continues, "Although some of the barriers are economic, they are in most cases institutional, political, and social." In other words, not much of a problem. And when the energy crisis was over though, attention for energy efficiency soon faded. But it has made a comeback with a vengeance as the climate change and financial instability and geopolitical tension seemed to meet. And three decades later in 2009, McKinsey, an important global consulting firm still found that there are huge unused energy efficiency potential. And by then it had become clear that the barriers are persistent. And not only in the U.S. there's unused potential because also the IEA, the energy think tank of the OECD recently stated that a huge opportunity is going unrealized. It projects that two-thirds of the economic potential to improve energy efficiency will remain untapped by 2035. So, that means we're living suboptimal in terms of welfare. And this potential exists in all sectors as you can see on this slide. So, there seems to be a huge gap between what is economic and what is actually realized.

So, here we have a display of seemingly and persistently uneconomic behavior. We say there is an apparent reality, something that you observe, that some energy efficiency technologies that would be socially efficient, so you can read net welfare increasing are not adopted. That's what they call the energy efficiency gap. It becomes paradoxical though when we take a private perspective because standard economic theory would expect consumers and firms to minimize costs. But much of the energy efficiency gap is said to come from the apparent reality that some energy efficiency technologies that would pay off for energy users are nevertheless not adopted. You could say they're leaving money on the ground.

For economists, this is an empirical anomaly or more popularly a paradox. It is what is referred to as the energy efficiency paradox. The efficiency paradox is a narrower version of the efficiency gap as you understand from these two quotes. So, here we are. Yes, but no. Yes, that energy efficiency measure is profitable but no, we do not adopt it. So, the question we are then faced with is the following: "So, why do we stand here confronted, as Pogo said, by insurmountable opportunities?" That's what Amory Lovins of the Rocky Mountain Institute wrote in 1976 after the first oil crisis. More formally, you can phrase it as follows: "If conservation actions are rational, then why shouldn't government simply wait for market forces to cause these actions?" This is a quote by Blumstein et al., one of the first to academically investigate this apparent gap between reality and theory.

So, let's take a deeper look into the gap? So, close to four decades have passed since first academic interest in this phenomenon and those decades have produced many studies that offer answers to the question. So, many explanations of why an energy efficiency gap exists or why there is a paradox. So, let's dissect this phenomenon a little bit. Here in this graph at the bottom we have the current practice, so the baseline efficiency level and higher up we find the technologist economic potential. So, that's what the IEA and McKinsey and Daniel Yergin calculated.

It's the potential calculated based on the benefits and cost of available technologies given expected energy prices. So, the potential optimal efficiency is even higher if we account for market failures in energy markets. For example, if we take into account social costs, costs by the use of energy that are currently not included in the price of energy such as pollution and health effects, which you call negative external costs, so you could say the "fair" price of energy would probably be higher which would make more efficiency measure profitable so the potential increases. So, now here we have the energy efficiency gap between the ultimate potential and the baseline and here we have the potentially a paradox between the private optimum as calculated by a technologist and the baseline.

So, there are different fields to offer different explanations for this paradox. So, let's have a look at those explanations. First, there is the diehard classical economists. There are not many, but they say that a paradox not exist, and they say that there's little reason to think that households and companies invest sub optimally, that they are in fact minimizing their costs. They blame it on the calculations of the potential. They say that those are wrong and that because they do not consider important costs and specificities of the energy users.

So, if you take a user perspective, decisions are more or less optimal. Most neo-classical economists, however, say, "Well, energy users may indeed make cost minimizing investment decisions and the paradox is much smaller probably than it may seem because of such errors in measurement and modeling." But there's evidence that markets for energy efficient products are not efficient and that market failures exist to lead energy users to make decisions that are not in their firm's or their personal best interest. So, they cost privately and socially sub optimal welfare outcomes and would provide legitimate reasons for policy interventions.

So, what remains between the technologist's economic potential and the neo-classical economics potential is those errors in measurement, the modeling. But with this explanation, there remains a paradox and a potential higher level of optimal efficiency investments. Okay. Neo-classical economics stop here, but behavioral economists and organization theorists turn their attention from markets to the actors, like households and companies and say that consumers and organizations do not make cost minimizing decisions. They show consistent deviations from the supposed optimal behavior. So, for example, so let's go there. Here.

For example, we tend to put more weight on the costs than on the benefits of investments. It's called loss aversion. And such biases lead to sub optimal welfare outcomes. And these biases can also legitimize both interventions, interventions to, as some say, help consumers and firms help themselves. And, this race is to optimal efficacy level some more so a little bit higher. So, now—and there will still remain some errors in measurement and modeling in the little gap between the technology's economic potential and the behavioral economic potential. So, the paradox, according to them, is a bit large than according to a neo-classical economist, but not as large as initially it seemed.

Okay, so now we have four steps between the ultimate potential and the baseline. So, in the process I've said that market failures and behavioral biases lead to sub optimal decision making and that those would provide legitimate reasons for policy interventions, so not the errors. So, we can try to raise the level of efficiency by eliminating those market failures and those biases using policy instruments. However, those policy instruments are rarely 100 per cent effective and they come with their own costs, so it only makes sense to employ the policies that are cost effective themselves because we cannot achieve the full behavioral economist potential.

Inefficiencies will remain and modeling and measurement errors must not be corrected by policies. So, if we eliminate, what can be eliminated? This is the behavioral biases and the market failures in an efficient way then we reach a higher level of potential but still below the behavior economists potential. And there remains a part that cannot be—yeah, that we cannot get at. So, we have a narrow social optimum if we didn't move beyond the private perspective to the social perspective. We can raise the efficiency level a bit more by correcting the market failures in the energy markets and so raise the private optimum which induces more energy efficiency investments.

Okay. So, now you got a theoretical understanding of the energy efficiency and the paradox. Now let's look at some practical examples for each of these steps. So, between the baseline and the ultimate potential and what are examples of failures, biases and errors. So, here you see the four steps again on the left side or the middle column and errors to market failure to systematic biases and the market failures in energy markets. And in the right column I listed some examples of such errors, failures and biases which can act as what we call barriers to adoption of energy efficient technologies. So, if you go to measurement and modeling errors, we see that they hold explanations for why the potential of energy and thus the gap is overestimated. For example, there may be hidden costs, right, such as overhead and transaction costs and costs that are real—those are costs that are real to the adopter but that are hidden to the observer. They do not feature into the potential calculations.

Or the heterogeneity of firms and households. And so what is profitable for the average firm or household may not be profitable for all firms so not all will adopt. Further, new technologies may entail more risk and uncertainty and because there's not much experience with those technologies yet which would rightly cause caution in decision making. And they may also have inferior performance on non-energy aspects. For example, efficient lights are more efficient by definition, but their tone used to be, at least until recently, less pleasing. So, you can see they may cause barrier to adoption. Now if you go to markets for energy efficient products, we can see they may not work efficiently because of several reasons. For example, buyers may lack information on the technologies and sellers may not know buyers' preferences so there's imperfect information.

Information can be asymmetric where buyers and sells do not have the same information and would, for example, make it hard for the buyers to judge the performance of an efficient product. Third, the buys may prefer to postpone the adoption if they expect any cost reductions or want to learn from others who adopt first. So, there's the learning by using effect. And finally, they have principal-agent relationships which means that there is a mismatch incentives between for example a landlord and a tenant so where one makes the investment while the other enjoys the benefits. So, the one who's making the investment may not have incentive to do so if he cannot enjoy the benefits.

Okay. Then third examples of behavioral barriers are a loss aversion, I already mentioned that, which leads to consumers to disproportionately weigh the investment cost against the benefits of reduced energy expenditures so [Cuts Out] under investment. Attention may be biased so information may be perfect but may not be consumed or understood because the source is not trusted by the user. And finally, many firms or rationality of firms can be bounded since they do not have the time and resources to assess all information and have limits to the times and skills they have leading to sub optimal investment decisions.

And then finally at the bottom you see that market failures and energy markets which can explain the difference between the gap and the paradox. So, these may include the unpriced external cost of energy use such as the environmental and the cost, for example, to guarantee a secure supply. Correcting those will not change the social optimum but brings the private optimum closer to the social optimum. All right, so that said, the theoretical introduction now, it clarifies some of the—well, it helps you understand the energy efficiency gap and the energy efficiency paradox. I'd now like to present an example of research that we did into adoption and rejection of energy efficiency measures. And this is a research that focused on the commercial and services sector in Germany. It's a work that was published in Ecological Economics, so you can find it there if you're interested in all the details.

And the question we asked in this study was: how are adoption and barriers to adoption of Energy Efficiency Measures related to the characteristics of the company and of the technology? So, the first two blocks on the left. Normally there are three types of factors that can affect adoption in addition to the organizational characteristics and the correct characteristics of the energy efficiency measured, there's also the context, but we leave that out of consideration. So, we focused on our organizational characteristics and the energy efficiency measures and these three relationships so also want to see whether the effect of the organizational characteristics on the adoption and the barriers is affected by technologies basically, right, are dependent technologies.

So, how did we do that? We used a representative large sample survey among commercial and service sector firms in Germany. So, we asked close to 2500 firms about their adoption and reasons for not adopting if they haven't and _____ sector. First, it's quite a large sector so it comprises 16 per cent of energy end-use in Germany. And according to studies there is a considerable efficiency gap in this sector of 141 petajoules. And this gap exists mostly in auxiliary, building-related measures, so not in core processes but in efficiency measures that are related to the buildings of these companies which includes such things as lighting, insulation and heating systems. So, those are the efficiency measures that we focus on. And you see them on the right, how we have efficient lighting, insulation, heating system replacement and also more operational measure, the optimization of the heating system operations.

So, those measures are cross-cutting. It means they're not specific for any type of firm per se. They involve ancillary functions so are not part of the core process of most firms and they're heterogeneous so they're different in nature and yet not too specific. They comprise some groups of technologies within which there's variation of course. So, what we do is we ask about adoption and barriers. So, first we adopt—did you adopt in the recent past? Now if they say no, we ask, "Did you consider?" So, we are going to find first who actively rejected the adoption of these measures. And so, because if they say, "Yes, we did consider but no, we did not adopt," we know, okay, they made their decision to reject and then we ask which of 13 barriers they thought were relevant to their decision. And then we also ask about other factors that you want to relate to these decision. First of all, there are factors related to agency so to get the principal agent relationships and factors relating to absorptive capacity and in this case energy-specific absorptive capacity, basically energy-related knowledge.

All right. So, then our research model becomes or at least the part that I'm going to talk about today, it looks like this, so we look at the organizational characteristics and their effects on the probability for adoption first. We split the organizational characteristics in two groups. Of course, we look at the agency factors, so is there a case of split incentive, so is the decision made in a different part of the organization than where the energy costs are paid for example and we look at absorptive capacity, so the—it's the capacity of a firm to acquire, absorb and transform knowledge into value basically which is dependent in this case on their prior knowledge of energy and _____ issues.

So, within the agency factors we have three variables or, yeah, the proxies that we use that represent agency factors. So, first, whether there's ownership of the building so whether they're renters or not. At the level below that, is there ownership of the energy supply equipment, in this case the heating system and is the firm in question a subsidiary or a branch of a larger firm so this may be a source of split incentives. Within the absorptive capacity factors, we look at energy management variables. So, is there an energy manager, is there an energy management system, have to have an energy audit to assess if there are profitable energy efficiency measures in their company that they could take and whether they are currently using renewable or clean energy.

So, these are factors that would suggest a higher level of energy-specific knowledge which we hypothesis would make them more aware of the benefits of energy efficiency and thus have an effect on the adoption. Okay. Now let's see what we got in the results. So, here we have the results of the probability of adoption. So, this is a complex table, but you see here, the variables on the left side, so the numbers tell you whether there's a positive or negative relationship with the probability of adoption. So, first, look at the technologies. So, for lighting, for example, we see that the probability of adoption is higher than for heating operations. And so that's the base category. That's where we have to compare to. And for insulation you see that the rate of adoption is lower than for heating operation. So, this basically reflects the turnover rate of these technologies as well.

Now let's look at the agency factors here below. So, direct tells you the relationship is negative and statistically significant. So, for all these agency factors, we see that there's negative relationship with adoption and as we expected. So, if the firm is a tenant, so renting the spaces, it's less likely to adopt energy efficient technologies, same if the heating system is external to the firm, so they have no control of it and also if the firm is a subsidiary it's more—it's less likely to have adopted the best energy efficiency technologies. So, that's evidence in support of our expectation. If you look at the absorptive capacity factors, we have significant results for the environmental and energy manager and whether they have an energy audit and whether they had used renewable—are using or—renewable clean energy. And these relationships, they're positive also as we expect. So, here we have support for the positive effect of energy-specific absorptive capacity of a firm.

Okay. So, that's cool. But now if you look at the individual technologies, so lighting, insulation, heating replacement and heating operations, each in its own column, it's a more complex pattern. For example, if you're a tenant, the heating operation's adoption is much less likely, but not necessarily for the other technologies. So, this could be interesting. You could explain it by heating operations. It may involve some adaptations of the system, the heating system in the building that's not the heater itself which is more tied to the building itself in which the tenant has less control over. So, that's one possible explanation. If the heating system is external, you have no control over it and it has affect over adopting energy efficiency measures related to heating but not to lighting and insulation so that makes sense, et cetera. But overall, the pattern is in favor of our hypothesis then that the absorptive capacity helps. I know that the presence of agency problems could cause a lower rate of adoption or it's, yeah, good.

Then below there you see, for example, if you look at energy audit, that's an interesting one. It has a positive effect on adoption of all different technologies so that adds to the evidence that all that exists, that energy audits could be an effective tool for promotion of energy efficiency adoption. All right. Okay, now let's—so the organizational characteristics have an effect on the adoption. Now let's look at the barriers. So, what reasons exist for not adopting? Now here's a very complex slide or very small letters, but it's not too complicated. So, here we have the four technologies, so lighting, insulation, heating system replacement and heating system operation for each of the technologies that lists the 13 barriers we asked them about and which percentage said, yes, this is a relevant barrier. And the order of the barriers is the same in each of these graphs and you see the pattern is quite similar as well.

So, the reasons for rejecting these technologies is not so technology dependent it seems. And you see one stands out quite significantly and that's the spaces are leased or rented. Yeah, so signaling a landlord-tenant issue. For you have too high investment costs as important barriers and the fact that there are other priorities, the firm has other priorities than energy efficiency. We'll talk more about that later maybe. But you see that the pattern is quite significant, and you also see at the bottom _____ risk and risk for quality of the product and risk for the production process for interruptions of the production process is not so important. Well, it makes sense because we're not talking about technologies that are directly related to the production process.

Okay. Now—and we also related the organizational characteristics to the landlord-tenant barrier. So, which organizational characteristics, the same as we just saw in the other table have an effect on the likelihood that a company reports landlord-tenant as a barrier. So, if you look at the technologies first at the top, you see that there's only effect for lighting and it's negative. So, for lighting, if we're talking about lighting, the likelihood that the company mentions that the fact that their spaces are rented is a barrier is less likely. It makes sense. Lighting is less attached to the building and often tenants can change it. So, they have control over it.

But the other technologies is less the case. Now what can—if you look for guidance in what can relieve this barrier or mitigate it, we look at the tenant thing. No, it's not quite the case and of course the tenant suggest there's a positive relationship with this barrier and tells us that if you're a tenant you're very likely to run into this barrier. And on top of that, regardless of tenancy, if heating system is external to your firm and if you have no control over it, you're also more likely to say this is a barrier. It adds to the problem of tenancy I'd say.

In the orange variables, the absorptive capacity factors, we see that the energy audit here reduces the likelihood that the—the fact that spaces are rented is a significant barrier so that maybe an instrument that can help overcome this most significant barriers that we identify so okay. Okay. So, to conclude this study, we see that the organizational characteristics have effect on adoptions or that there is a relationship. So, agency problems, whether they're external, if your spaces or rented, or internal, if your subsidy can hinder adoption of energy efficiency measures and they also can be technology specific. So, if you're talking about the heating system, if you're not a tenant but the heating system is external to your firm because you are a small firm and you share the building with other firms and the heating system is essential to the firm, you run into the same problem.

And we also see that the energy knowledge resources, so the energy-specific absorptive capacity is associated with higher adoption. Now on the barriers, having identified the most relevant ones which is the owner-user dilemma or landlord-tenant dilemma, the investment costs and the other priorities that the firms have and the least relevant is the technical risk of the barrier. So, that's what we can learn from it that has some implications for policy. So, first of all, how can we overcome the agency problem, the split incentives between landlord and tenants and subsidiaries and mother companies? Well, the common use of communication devices to reduce the information asymmetries. We saw that energy audits might be effective in doing so. Energy and eco-labeling is also used to overcome such barriers and it has been shown before that eco-labeling can indeed be a communication tool that makes potential renters of commercial spaces willing to pay a higher rent for affordability. So, that can be effective.

Another way to do it is to overcome the split incentive is to bundle the risk and rewards in a separate entity like an energy service company. Okay. Now if you look at what can enhance ability to acquire, assimilate, and exploit energy-related knowledge and to increase absorptive capacity you can look at the audits to enhance the awareness of the firm, so it learns from having an audit what is possible within the firm. EU is already requiring this from I think especially larger firms and suggesting, encouraging it for smaller firms. Then for larger firms you can also promote energy management, but it may be a bit over the top for smaller firms, but for smaller firms ESCOs may be able to provide a solution and they could provide scale that doesn't exist by aggregating very small quantities.

All right. That was the first study. The second study is a bit shorter. Now let's look at what a subsidy can do for residential energy efficiency upgrades. So, we're moving to households and specifically interest in the effect of free riding. As we know, many companies or many governments and also utilities use subsidies to promote energy efficiency upgrades, but the effectiveness of subsidies is often overestimated because there's such effect as the rebound effect, moral hazard and postponing adoption when you think a subsidy is coming and free riding, so using the subsidy when you actually don't need it.

So, these free ride estimates are quite important. And usually when you look at subsidy programs after they've been implemented, you find large variation in the amount of free riding but typically about 50 per cent. So, 50 per cent of those who enjoy the subsidy would not have needed it to adopt. So, that's huge inefficiency. But of course, you want to know before you implement the subsidy what you can expect in terms of free riding. So, here we use data from a household survey in eight EU countries. So, you see the number of respondents and which countries investigated as part of the—as research within the H 20—Horizon 2020 risky project. It's EU funded.

So, we look at households that serve as representatives and in total we have 10,000 respondents. So, we propose them a hypothetical heating system replacement. But first we ask, "Are you planning to replace your heating system in the next five years?" If they say, "Yes," we say, okay, stop the survey because they would adopt anyway, we can say they are free rider. So, if the service is implemented they would enjoy it but not have needed it. Now those who say no or don't know could be incited to adopt with a subsidy. So, they enter into a choice experiment in which you offer hypothetical heating system which is a bit more efficient than a current one and we say that it costs 2000 euros and it would save them a total amount of X euros over T years and we vary those amounts. Now if they say, yes, we adopt, we know, they are also probably a free rider because we have not offered a subsidy yet, but they just needed to be confronted with this offer. So, that's what we call an observed weak free rider. If they say no, then we offer them a subsidy and if they then adopt, they're incentivized to adopt so they react to subsidy and their level subsidy that they would need to adopt would be between zero and this level of subsidy. And if they say no, they're a non-adopter and all the subsidy would be at least higher than the level that we offered.

So, now we can estimate the distribution of the threshold subsidy in households in those EU countries. So, we assume that this is normal distribution and we have fitted to the data and then first we do this for all countries combined and then we see that the mean and median threshold rebates so the level at which half of those in the experiment would adopt the heating system is 775 euros. But you see there's a significant part that extends below zero and these are what we call free riders. Their threshold subsidy would be less than zero. So, those we call weak free riders and they did not say that they have plans to adopt but confronted with the offer they say, "Yes, we adopt."

All right, now if we do that for all countries, we see consistently high levels of median subsidy and so remember, the heating system itself was priced at 2000 euros so the subsidies are close to—somewhere between—some are very low in Poland and Romania and some very high in Sweden so 40 per cent or so of the total cost of the heating system with considerable variation. Now we can use this information to see what is the share of free riders that we expect for any level of subsidy.

Now here we have subsidy levels on the horizontal axis. It's the same for each of these graphs, between zero and a 1000 euros. 1000 euros is half of the cost of the heating system. And the solid line tells you the total share of free riders and so the strong free riders and the weak free riders. Now you can see that in all the countries it's quite high and remains above 50 per cent, even at 1000 euros subsidy. I can see it's highest in Germany and Italy and lowest in Romania. Okay, so it's quite significant. And you can also see that the share of weak free riders, that's the dashed black line, is higher than the strong free rider so it's a large amount. Except for Romania, that's the inverse, so a large share of strong free riders but in Romania something special's going on. They are currently in the process of updating old inefficient central heating to more modern systems so a special case.

Okay, conclusions. [Laughter] So, with choice experiments, we can get an estimate of free riding before implementing a subsidy and the numbers correspond quite credibly with the numbers that you get from evaluating free riding after the subsidy. And the free riders make up a large share of the expected beneficiaries so it's more 50 per cent of the rebate of 1000 euros. So, that makes such a program much more inefficient. We can find relatively high rebate estimates across the board and so premature replacement is not something people easily do. Not [cuts out] quite some money to incite them to, well, compensate them for their capital loss.

And we also saw that the subsidy itself or the offer of a subsidy may function as an information device which causes potential households who would not have needed the subsidy to adopt and to enjoy the subsidy. So, in terms of implications, yeah, so the first thing I already told you the free riding makes subsidy heating systems upgrades quite expensive. But we also see that there are differences between countries. So, if you can coordinate between countries and you can target those countries where the efficiency is highest and then progressively go forward to the other countries where it's less efficient depending on how much your target for target conservation or greenhouse emissions is in a European setting that could be possible.

Okay. So, those are two examples. Now I'm reaching the conclusion. So, I'm not the only one doing this research and so many other people are looking at the same kind of questions but in different setting with different technologies, different countries, different users. But still, so—and this yields practical policy advice, but still today and more than ever, governments and energy experts are still touting energy efficiency as a win-win, as a motor for growth and job creation. So, there's the European Commission, for example, says that the review of the energy efficiency legislation unlocks the energy savings that can boost growth in the U.S. economy. So, energy savings have been locked and so 50 euro bills have been lying around behind the barriers that we so far fail to remove. So, there's still a gap despite all this work.

So, one may wonder after four decades of energy efficiency gap, what have we been doing? Should the conclusion be then that the energy efficiency gap is not an anomaly but a defining inseparable characteristic for energy efficiency and that we have to accept it? I think not. I think you have to realize that a diffusion of innovation is always gradual so reality's inevitably behind the current optimal level and the assessments of efficiency potential do tend to be too optimistic. But I'd rather say that four decades of research have improved our understanding of the diffusion of energy efficiency measures and that the sustained gap is a sign of both ongoing innovation and plenty of open questions for research.

But if we get desperate we can call the IEA for consolation. The IEA's keeping a finger on the pulse of energy efficiency progress. So, it sends a positive message. It's at—in each member countries which is most OECD countries. Energy consumption has been decreasing for ten years already and consumption is no longer following GDP. So, here on this graph the economic activity which it relates to GDP is the upper graph and the upper line, upper curve, the activity effect. So, that's growing. But the total final energy consumption is this orange curve which has been decreasing over the past ten years and largely due to the efficiency gains made at the green curve at the bottom.

So, consumption seems to be no longer following the GDP so two-thirds of this decoupling is allocated to the efficiency effects. [Cuts out] now of course GDP and energy use are still coupled of course. More GDP leads to higher energy consumption, but the notification factor has decreased fast enough to keep the energy use flat while the GDP rose. So, that is good news. But this now includes big emerging economies and cannot disprove that adoption rates of energy efficiency are still sub optimal. So, the work goes on and our work is never over. Improvement in global energy efficiency slowed down dramatically in 2017 and was ____ the cost by an apparent weakening of the efficiency policy coverage and its stringency and by lower energy prices as well.

So, you can see in this graph how much global energy intensity improved each year and you see in 2017 it was much lower than in the previous years and about half of what would be needed to be consistent with the two degrees target so consistent with the Paris Climate Agreement. And efficiency improvements in 2017 were also not sufficient to counteract the effect of higher economic growth so it is in 2017 led to an increase in global energy related carbon emissions. And so, we have weaker coupling, not per se decoupling. So, closing the gap, it means increasing the effort and sustaining the effort.

Okay, so from my perspective I can see three ongoing emerging trends for energy efficiency research. At first probably there'll be more emphasis on policy evaluations. So, they're increasingly relevant and urgent and we want results but also data availability's growing and the heterogeneity of the measures and the users limits the transferability of policy evaluations to other settings so it's work that needs to be repeated over and over again.

And finally, management will become more focused so from a management school that's interesting. It's the boundary between the supply and demand side of energy system is blurring so if you have solar panels and wind turbines to make consumers become prosumers as my colleague told you a few weeks ago.

So, producers and consumers of energy at the same time and demand response, so load shifts, load management is coming up. And that is interacting with energy efficiency. So, energy management is coming to the micro level, to the level of households and firm and besides many efficiency measures are behavioral or operational as they're not technological. So, this puts the focus also on behavioral and managerial aspects. So, energy management is likely becoming more strategic and the capabilities of many firms to manage energy use are still underdeveloped so there's something to gain. So, the work is never over, but I'm hopeful that one day governments can stop championing energy efficiency and that we may be studying an inverse gap and that profitable energy efficiency measures have been exhausted but adoption continues and that we can say, no, but yes. Just kidding. That would be inefficient. But thank you very much for tuning in. If you want to learn more about us, here you have the link to our website and our contact details. So, please be in touch.

Katie Wonderful. Thank you, Mark, for that outstanding presentation. As we shift to the Q&A I just want to remind our attendees to submit the questions using the questions pane at any time. We'll also keep several links up on the screen throughout for quick reference to point to where you'll find information about upcoming previously held webinars and how to take advantage of the Ask an Expert program. Our first question—we have a couple of questions to ask for the remaining of the time. Mark, our first question is: you showed what was the most important barriers for companies and the commercial and service sector, what can you say about households and their barriers and what are the main barriers that keep them from investing in energy efficiency?

Mark Yes. Well, yeah, we talked about commercial and services sectors and we saw that the landlord-tenant dilemma, so the problem of renting spaces is a major barrier and that holds for households too. So, in many countries, 20 to 50 per cent or so of the households are renting their residence. So, there you have the landlord-tenant problem, that's a big issue. And it matters what is provided with a rental home and it also varies. So, if the appliances are included, which is the case in some countries, when I lived in the U.S. for example, the fridge, et cetera was part of the apartment, and then the split incentives apply to those as well. And that adds to the dilemma in addition to the equipment that this fixed to the building.

So, the split incentives is a huge one and furthermore the attention biases are major obstacles. So, when it comes to appliances and cars, for instance, people tend to give no or very little attention to energy costs. So, all attention is on the investment. So, to a certain extent it makes sense because energy is not often a very large share of a household's budget. So, maybe don't have much attention to the cost and so—but we now have energy labels to help consumers take into account those energy costs like in the U.S. you have Energy Star and in Europe you have these energy performance certificates. And they work. They work almost too well in the sense that people use them as a decision heuristic. So, they base their decision on the label color and do not pay attention to the differences among the appliances within the same label color.

And then you get the effect that the manufacturers have no incentive to go beyond the minimum level of what is required to get a good label color. And there's another effect of this attention bias. For example, the metrics that are used matter as well. And so, for cars for example, there are studies that show that the miles per gallon metric is counterintuitive so people intuitively associate larger numbers with higher fuel consumptions so less efficiency while it's of course the reverse. So, I was going to say for households you have split incentives, attention biases that are important barriers I'd say. Can say that those are the most important or at least very important.

Katie Thank you, Mark. And I think we have time for one more question. The percentages of free riders you mentioned during your presentation was really high, surprising, if free riders make subsidizing energy efficiency upgrades so much more costly, why is it quite common to use subsidies to promote efficiency?

Mark Yeah. That's a very good question. I think that in theory subsidies can be efficient, but it depends on the situation. If they realize that our study involved a rather marginal efficiency improvements and normal households who did not have very a very new heating system. So, they were among you could say the more likely to be convinced to upgrade. So, the potential for free riders was quite high there, however it can be effective, maybe even necessary in situations where people have not shown any adoption, having failed to upgrade and where there are many potential social benefits to capture as well that help to justify the subsidy.

And so, for example, among households with little means in—who live in leaky houses which the French have a nice word for that, they call it energy colanders, so in those places the investment costs are just prohibitive for poor households. But the potential gains are quite large. So, there, the risk of free riding is low and the potential social benefits are quite high and so there's much to gain. And a better insulated home on top of more efficiency and reduced energy costs could also reduce the health issues and improve the well-being and possibly the productivity of its inhabitants so that would save on other social costs and it would add to the justification of such a subsidy. So, you can see, for example, programs which used this approach.

So, subsidies for renovation, for example, are often targeted to households who are trapped in poverty. In U.S. you have the Weatherization Assistance Program, for example, who does that and in France you have the French Renovation Policy which also prioritizes houses that you could say strain energy and so where most benefit is expected. So, targeted subsidies can still be very—can still be efficient.

Katie

Great. Thank you again. On behalf of the Clean Energy Solutions Center I'd like to extend a thank you to Mark and all our attendees for participating in today's webinar. We very much appreciate your time and hope in return that there was some valuable insights that you can take back to your ministry, departments and organizations. We also invite you to inform your colleagues, to those in your networks about the Solutions Center resources and services including no-cost policy support for our Ask an Expert service.

I invite you to check the Solutions Center website if you'd like to view the slides and listen to the recording of today's presentation as well as previously held webinars. Additionally, you'll find information on upcoming webinars and other training events. We are now posting the webinar recordings to the Clean Energy Solutions Center YouTube channel. Please allow about a week for this to be posted. Finally, I'd like to kindly ask you to take a moment to complete the short survey that will appear when we conclude the webinar. Please enjoy the rest of your day and we hope to see you again at Clean Energy Solutions Center events. This concludes our webinar.