Charles University in Prague

Faculty of Social Sciences
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MASTER THESIS

Somewhat cloudy with a chance of sunshine: Analysis of renewable energy generation support schemes

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

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Signature

Acknowledgments

Abstract

Support for electricity generation from renewable energy sources is one of measures aimed at switch of European economies from fossil fuels to renewables. In the past a lot of attention was paid to the theoretical assessment of different support schemes, however, analysis of the empirical data on those schemes is somewhat lacking. This thesis analyses assessment of two types of support schemes in three countries on empirical data. The main contribution of this work is (i) expansion of previously used methodology that analyses relationship between investments into electricity generation from renewable energy and the net present value of such investments, and (ii) inclusion of the Czech Republic into the list of observed countries.

JEL Classification	E61, O31, O33, O38, Q28, Q42
Keywords	renewables, RES-E, photovoltaics
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Abstrakt

Podpora výroby elektřiny z obnovitelných zdrojů energie je jedním z nástrojů zaměřených na přechod evropských ekonomik od fosilních paliv k obnovitelné energetice. Zatímco teoretickému hodnocení jednotlivých druhů podpory byl v minulosti věnován dostatek prostoru, literatura hodnotící praktické fungování těchto systémů příliš rozsáhlá není. Tato diplomová práce se zabývá analýzou dvou druhů podpůrných systémů ve třech zemích postavenou na empirických datech. Hlavním přínosem této práce je (i) rozšíření metodologie, které je užíváno při analýze návratnosti investic do obnovitelných zdrojů, a (ii) zařazení České republiky mezi analyzované země.

Klasifikace	E61, O31, O33, O38, Q28, Q42
Klíčová slova	renewables, RES-E, photovoltaics
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Acronyms

BNEF	Bloomberg New Energy Finance
CAPEX	Capital expenditures
CEP	Climate and Energy Package of the European Union
DSCR	Debt service coverage ratio
EBITDA	Earnings before tax, depreciation and amortization
EU ETS	Emission trading scheme of the European Union
FIT	Feed-in tariff (also **tariff-based support scheme**)
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return (discount rate at which NPV of cash flows equals zero)
NPV	Net present value (sum of all discounted cash flows)
NREAP	National renewable energy action plan
OPEX	Operational expenditures
PV	Photovoltaics, electricity production from solar irradiation
PV1	Class of small PV sources with installed capacity of max. 30 kWp
PV2	Class of medium PV sources with installed capacity of max. 100 kWp
PV3	Class of large PV sources with installed capacity of max. 1 MWp
PV4	Class of PV sources with installed capacity over 1 MWp and brownfield installations
R&D	Research and development
RES-E	Electricity from renewable energy sources
RO	Renewable Obligation, certificate-based RES-E support scheme of the UK
TGC	Tradeable green certificate (also **certificate-based support scheme** or **renewable obligation certificate**, **ROC**, in the UK)
W	Watt
WACC	Weighted average cost of capital
Wh	Watt hour
Wp	Watt peak

Master Thesis Proposal

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Proposed Topic:

Somewhat cloudy with a chance of sunshine: Analysis of renewable energy generation support schemes

Topic Characteristics:

The 2020 target for electricity generation from renewable energy sources (RES-E) is one of the most ambitious environmental projects in the European Union. In order to achieve the desired share of RES-E in electricity generation, a number of fairly different support schemes are used in the member states in order to compensate the RES-E producers for higher costs in comparison to the "black energy" sources. The two general support scheme designs differ in the variable set by the market regulator in order to achieve the goals: the feed-in tariffs (FIT) offer guaranteed price for electricity from RES-E, while tradable green certificates (TGC) set quantity of electricity from renewables that must be included in the final electricity sales. This is done by letting the RES-E producers sell their electricity for market prices and creating a separate market for the certificates that are sold by the producers and bought by the sellers, grid operators or final consumers. The goals and methods are in greater detail described in the Directive on the promotion of the use of energy from renewable sources (2009/28/EC), the progress towards the goals is described in reports such as EREC (2011). Beside FIT and TGC, other measures of support, such as tax breaks and investment subsidies, are often used.

The outcomes of academic debate on the support systems differed substantially before and after their launch. Results of ex-ante analyses were favorable for TGC, as it is a market solution with supposedly low costs and one that should promote investments into RES-E with high fixed costs investment. However, after some time in function, the caveats of the TGC design became clear: while assumption of overall efficiency was not rejected, the costs borne by electricity consumers were substantially higher than expected and the promotion of high fixed-cost RES-E staggered, as described cases of Flanders by Verbruggen (2009) and Sweden by Bergek and Jacobsson (2010). However, the FIT schemes established in most of the continental EU member states have soon revealed their weak points as well, in such cases as photovoltaic market crash in Spain or the PV market hoarding the Czech Republic went through last year. It is clear that the question of design of the support scheme is as crucial as the type of the scheme chosen (Ringel 2006): Differentiation of support among RES-E sources in TGC schemes (Madlener and Stagl 2005) or careful selection of properties of the selected FIT system (Couture and Gagnon 2010) are of great importance.

While rather vast, current literature on RES-E support schemes is limited to theoretical and partial analyses of properties of the systems, while the empirical studies usually do not contain models and make do with basic observations of empirical data. There is little to none literature that would contain any deeper data analysis. In my thesis, I would like to expand on existing literature and fill the gap that is currently left in the analysis. My aim is to construct a sequence of models that would describe operating of different versions of the two main support schemes under different conditions, with inclusion of other measures of RES support and interaction with EU ETS. The final output will assess strengths and weaknesses of each of the schemes under given terms and surroundings in which it operates and with respect to criteria of effectiveness, efficiency, equity and ability to stimulate technological progress in the RES-E market. Furthermore, use of RES for heating and cooling (RES-H) will be included in the analysis as well. In second part of the analysis, the model will be applied on real data from RES markets.

This approach will help assess the factors that led to problematic behavior of the support systems in the past as well as assess eligibility of currently used systems and describe the changes needed to make the systems sustainable in the future. Furthermore, within this framework, the "what-if" questions that

are currently left unanswered (what if electricity generation from biomass is left out from the support scheme? What if the fixed costs of RES-E electricity generation drop substantially?) will be tackled. Finally, the models will be generalized in order to assess conditions under which would be a single EU-wide support scheme feasible.

Hypotheses:

1. Neither FIT nor TGC are generally superior, suitability of a support scheme is conditional on many factors
2. Support schemes currently used in the EU need to be amended in order to ensure their sustainability and the attainability of their targets
3. Under certain conditions, common EU-wide support scheme is feasible.

Methodology:

The methodology of the paper will expand on previously devised models from literature, such as the probabilistic NPV model analysis by Falconett and Nagasaka (2010), FIT and TGC behavior under oligopolistic electricity market (Tamas et al. 2010) or papers on energy market modeling by Marchenko (2007, 2008 and other). Should there be no models available from literature, own models will be used where possible.

Outline:

1) Introduction
       a. what are renewable sources of energy (RES)
       b. reasons for integration of RES into energy mix
       c. in-depth description of various types of RES
       d. in-depth description of the two main RES support schemes including legislative drivers behind them
       e. other forms of RES support (tax breaks, investment subsidies, net metering and others)
2) Review of literature and assessment of current state of RES in the EU
       a. Review of impacts of various RES support schemes that are currently in use in the EU member states
       b. Review of relevant literature, review of progress of debate on the topic
       c. Short assessment of feasibility of single EU-wide support scheme for RES
3) Setup of the models,
       a. Selection of RES support scheme types used in the analysis
       b. NPV model (investor point of view)
       c. Support scheme costs model (network operator/final consumer point of view)
       d. Other partial models
       e. Prediction of share of RES in energy mix with respect to endogenous and exogenous factors (main model, using outputs of partial models b to e),
       f. Evaluation of the selected models
              i. in terms of effectiveness (ability to achieve goals, robustness and stability under changes in exogenous variables)
              ii. in terms of efficiency (costs of achieving desired state, DWL)
              iii. in terms of equity (allocation of costs among support scheme participants)
              iv. in terms of ability to stimulate technical progress (support schemes as a driver of new markets)
       g. generalization of the models for single European support scheme
4) Application of the models
       a. Ex-post analysis of past events
       b. Ex-ante application of the models on support schemes of different EU countries
       c. Analysis of feasibility and probable performance of single European support scheme
5) Conclusions

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1   Introduction

The inclusion of renewable energy in electricity generation, heat generation and transport is one of the essential topics in current energy and environmental policy, both in the European Union (EU) and globally. Success of these efforts is fundamentally dependent on policy tools designed to raise the share of renewables. Well-designed policies have the potential to change the shape of the market and bring it towards more self-sufficient, cleaner and economically less demanding state. However, misguided policies threaten not only the completion of these goals, but also the future state of the energy industry and the economy as a whole. In the European context, the inclusion of electricity generation from renewable energy sources (RES-E) into the mix had both positive and negative aspects. The experience of EU countries with renewable energy ranges from creation of RES-E market that works as planned in Germany on one end of the spectrum to market overheating in the case of photovoltaics in Spain and the Czech Republic or the inability to introduce enough renewable energy into the mix in the UK on the other. The motivation of this work is to find out what were the drivers of wider RES-E penetration in environment with the different experiences in the RES-E support.

In principle, there are three main measures by which renewable energy can be supported: feed-in-tarrifs, transferable green certificates, and direct subsidy. While the latter requires public sources to be spent that are scarce, the former two rely more on market forces and require less or even none public funding. My thesis aims at examining the first two support measures on RES-E.

In order to do that, two propositions are examined. The first proposition states that neither support schemes based on set tariffs paid out to RES-E producers nor schemes based on marketable certificates dominate each another in terms of effectiveness, efficiency, equity and research, development and diffusion at the same time. According to the economic theory, each of the two general support schemes excel in some areas and lacks in others. An analysis of the practical implications of already introduced support schemes is needed to confirm or reject the assumptions stemming from the economic theory. In order to verify this first proposition the performance of German and Czech tariff-based support schemes was compared to that of certificate-based support scheme currently used in the UK on wind RES-E data.

The second proposition states that the introduction of common support scheme in the two comparable EU member states, Germany and the Czech Republic, would bring about better results than the employment of separate schemes specific for each of the countries. RES-E support is a controversial issue in Czech Republic, this proposition is therefore motivated by effort to find out whether adaption of more robust German scheme would lead to more functional market in the Czech Republic. Photovoltaic (PV) data was used to test this proposition.

Introduction of right policies at the right time is of utmost importance in the case of renewables in the EU. This paper hopes to contribute to the debate on this topic by describing the issues that distinguish well-implemented RES-E support schemes from those that do not bring about desired outcomes. To the knowledge of the author there is little research at the moment that would approach the question of RES-E support from a viewpoint of investments into renewable energy in relationship to their net present value. Furthermore, the NPV calculations in this thesis utilize the country- and time-specific discount rate calculated in line with the CAPM methodology, as opposed to the constant discount rate usually employed in research papers. This approach captures the decision-making process of an investor in real world and takes into account varying conditions among different countries and years. Finally, no research has yet analyzed the Czech RES-E support scheme to such extent. Conclusions drawn in this work therefore shed some more light to issues heavily discussed in theoretical literature that have yet to be analyzed on empirical data.

The results of analysis performed in order to verify the first proposition suggest that it should be rejected. While the economic theory praises the certificate-based support schemes for their higher efficiency vis-à-vis that of the tariff-based ones, examination of the empirics of their works has shown that the certificate-based support schemes underperform in many areas. The main reason for this is the uncertainty to which are the investors in RES-E exposed and due to which they expect a much higher remuneration than their counterparts investing under the tariff-based scheme. The second proposition cannot be rejected. Even in the case the Czech tariff-based support scheme set-up only blindly copied the German one, the resulting state of Czech PV RES-E stock would be better than the current one. This shows that selection of an appropriate support scheme is necessary yet not sufficient for the creation of a well-rounded stock of PV RES-E. A scheme also needs to be administered by a competent regulator and under clear, unbiased rules. Only after that will the clouds disappear and the sun begin to shine.

The structure of this paper is as follows. First, a quick overview of relevant policies is presented, along with a general rationale for renewable energy support and an assessment of the properties of a RES-E support scheme in chapter 2. In the same chapter, the two main setups of RES-E support schemes are discussed in relation to their properties, followed by an assessment of the schemes in the countries in question. Second, the datasets used in preparation of this thesis are discussed along with the case of the wind energy in the three countries in chapter 3. Third, the models of relationship between installed capacity or count of photovoltaic installations and their net present value employing linear regression are presented in chapter 4. Four, the forecasting model is described and its results outlined in chapter 5. Results are discussed in the next chapter. The last chapter concludes.

2 Literature review and assessment of the topic

2.1 History of efforts in climate change, air pollution and renewable energy support

There is a general scientific agreement that carbon dioxide generated by human activities contributes to a large extent to climate change and its impacts on the way we live. According to the IPCC (2007) dire consequences of global warming include rapid increase of temperatures, extinction of species, floods and droughts and an increase in instances of extreme weather conditions. In order to halt the adverse development, the temperature rise that results to a large extent from carbon emissions needs to be contained at levels two degrees above the pre-industrial levels at most, as any temperature increase over this level will not be reversible.

Global change that would lead towards such a development is unlikely to happen without a joint action of governments throughout the world. Many environmental issues in the past were tackled by individual countries on the basis of quality of life improvements pushed by growing income of the societies. This relationship is described by the Kuznets curve: the pollution grows with rising income, just to revert and drop back with continuing economic growth. The inverted U shape relationship was previously observed in case of local air pollutants or water pollution: the emissions grow as the population gets richer, but as soon as the costs related to pollution restriction get lower than the perceived benefits from lower emission level, the emission trend changes from upward to a downward one.

However, such relationship does not (yet) hold for climate change. Yandle et al. (2002) explains this in relation to the global, directly unobservable nature of climate change. Indeed, while the impact of lower sulfur emissions on the quality of life at a place where the reductions took place is obvious, it is hard to perceive the immediate effect of a decline in carbon dioxide concentration in the atmosphere. Furthermore, any unilateral action in this direction is fruitless due to the global nature of the issue. In order to matter, the reductions need to be done in many places at the same time. This results in the tragedy of the commons, where no country will voluntarily begin to curb the emissions on its own, as its own benefit from such action is marginal. Another way to put it, the climate is being overused, and the

externality of its overuse is not properly priced. Without a widespread, binding agreement among most of the countries of the world, any attempt to mitigate climate change is destined to be an unsuccessful one.

The European Union set out to be a global leader in climate change mitigation. The measures of greenhouse gas emission reduction include carbon allowance trading under the Environmental trading scheme (EU ETS), renewable energy support, improvements to energy efficiency and others. The final goal of the EU is to create a carbon-free EU economy by the year 2050.

The means of achieving the climate goals of EU are summarized in the Climate and Energy package of the EU (CEP) that builds on two pieces of legislation, the European Commission (EC) communication COM/2007/0001 and directive 2009/28/EC (EC 2007 and EC 2009). The measures summed up in CEP should help the EU to achieve the three goals agreed upon by the EC in March 2007: a 20% drop in carbon dioxide (CO_2) emissions by 2020 compared to the 1990 level (or 30% should the non-EU countries join in as well); 20% of energy from renewable energy sources in total consumption in the year 2020; a 20% improvement in energy efficiency of the EU economies by 2020. Regarding renewable energy, the directive determines how the targets of renewable energy share in the energy mix will be distributed among the member states. It is up to the states to divide their commitment among the electricity, heat and transport sectors. In line with the directive, each of the states prepared a national renewable energy action plan (NREAP) on achieving the goal levels by 2020 before June 2010. In order to achieve the stated goals the renewables directive obliges the member states to create a support system that includes all the producers of electricity from renewable energy sources (RES-E). While the basic attributes of such systems are set, the member states are allowed to select whichever form of support scheme they deem most fit for their electricity market.

Inclusion of electricity from renewable sources influences more than just the emissions of carbon dioxide and other greenhouse gasses. Conventional sources of energy generate greenhouse gasses as well as local pollutants, switching away from conventional towards renewable therefore has local impacts too. Furthermore, successful inclusion of renewables into the mix would be followed by the phase-out of conventional sources that often depend on fuel from unstable regions, energy security is therefore another reason for current EU efforts.

Currently, the EU is switching away from "black" energy generation towards cleaner fossil fuels such as natural gas. Furthermore, some of the countries, most

noticeably Germany, are steering away from nuclear energy as well. Bearing these developments in mind, the success of renewable energy is of utmost importance. One must therefore cautiously review whether the RES-E support schemes under the current setup are a sufficient tool to attain the renewable goals – not only in the share of renewables in energy mix, but also in research and development (R&D) and technology diffusion acceleration or sufficient technology production capacities, that all at costs bearable by society.

2.2 History of efforts in climate change, air pollution and renewable energy support

In most of the cases, the costs of RES-E generation are prohibitive at current electricity prices. With the exception of biomass, the variable costs of the RES-E installations are sufficiently low and consist mostly of upkeep costs, as no fuel is needed in photovoltaic, wind and hydro RES-E sources. On the other hand, the fixed per kW investment costs are substantially higher than in case of coal or gas power plants. According to Breyer and Gerlach (2010), even with RES-E support schemes in place, only 70% of residential and 30% of industrial photovoltaic installations in the EU will be beyond grid parity[1] and therefore able to repay their costs solely by market electricity prices by mid-2010s. Furthermore, the load hours of most of the RES-E sources are substantially lower than those of other electricity sources. These two attributes of the RES-E sources combined make repayment of investment under current terms exceedingly long.

Another issue of RES-E generation is relatively the higher exposure of such installations to risk in comparison to conventional sources. In the electricity market, the conventional sources pose as a price-setter, the price therefore fluctuates in line with the variable costs of these sources and that roughly copies the development in prices of oil. The resulting revenues of conventional sources are therefore rather stable. Exact opposite however holds for RES-E sources, as described by Hood (2011). The above-mentioned ratio of fixed to variable costs means that while the variable costs the RES-E producers encounter are relatively low, the repayments of fixed costs are correspondingly high. These high, stable costs are to be repaid by fluctuating revenues that are out of the control of a RES-E producer. In other words,

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[1] Point at which the per kilowatt hour cost of a RES-E installation, including initial investment, operations and maintenance and other costs, equals price of of purchasing power from the electricity grid.

while the producer enjoys extraordinary profits in periods of high fossil fuel prices, he or she is not able to repay the costs when the price of fuel declines. This generates additional risk in comparison to other electricity production investments and extends the time a risk-averse investor expects to need to repay an investment into RES-E.

The costs related to bringing the RES-E towards grid parity with only limited risk exposition might be understood as overly large from a short-term perspective. As means of climate change mitigation, currently underdeveloped RES-E technologies are indeed a more costly solution compared to other options. Philibert (2011) argues that this notion stems from the short- rather than long-term approach to the issue. The early development of the RES-E induces a level of research and development that would not be sustainable under regular circumstances. Acceleration in diffusion of RES-E technologies, both among the producers and among states and countries, helps to build the groundwork for more intensive usage of these technologies in the future, as it puts pressure on the creation of infrastructure ready for RES-E sources, raises the knowledge of how the technology works and, most importantly, attracts funds to a market that would otherwise be only niche. These impacts of current RES-E support schemes will lead to substantial cost reductions in the future. This is already apparent on case of photovoltaic industry expansion in the last few years: Since the beginning of operations of the support schemes, the demand for PV technologies have grown. The inflow of funds to PV technology producers has helped finance research in the field and has attracted companies to invest into production capacities, resulting in a steep decline of costs and growth of efficiency of PV panels. Put together, with the future large-scale deployment of these technologies in mind, the current costs of RES-E support schemes are not as large as sometimes understood, despite the fact that there are cheaper short-term solutions such as fuel switching.

Successful and sustainable inclusion of RES-E into energy mix is conditional on a number of factors. Progress in electricity generation efficiency, costs and other attributes that can be improved by the research and development (R&D) are crucial for large-scale development of renewable electricity and for sustainable continuation of the RES-E market after closing of support schemes. The usual approach to the development of technologies is based on the classical theory of a learning curve. According to the theory, the efficiency of a tool (or costs related to usage of such tool) improves with time, or in other words the increase in experience with a technology leads to lower costs of its use. For technology this relationship is represented by the progress ratio defined as cost reduction per doubling of cumulative installed capacity that stays approximately the same throughout the whole life of a technology. Nemet (2006) expands on the theory and includes other points of

influence into the mix. In the selected case of solar modules the influence of experience is supplemented with knowledge spill-over or market dynamics. The author further decoupled time development of this technology to find the drivers behind module efficiency improvements. Out of sixteen identified points, ten were related to R&D programs started either directly or indirectly by government schemes. It is therefore expectable that actions of governments aimed at R&D promotion might indeed spur the development.

R&D in the area of renewables is plagued by a number of market failures that cause lower than socially optimal investments into this field. Parry and Goulder (2008) address the issue of knowledge spill-over. Returns from a research project will be only partially captured by the original investor, as the results will be either used by others or emulated in the case of presence of patent laws, as described by Jaffe et al. (2000). While the investor bears the total cost of the research project, his or her marginal benefit will be distinctively lower than the benefit to society. A technology that improves the efficiency of a renewable electricity generation brings both direct cost benefits to the society via lower electricity prices and indirect environmental benefits, but the originator of such improvement fails to capture most of the returns. Griliches (1992) argues that the appropriability problem might also have positive consequences, because the diffusion of knowledge allows others to build upon it, although the net effect of the R&D spill-over is negative. There is no way to solve the appropriability problem, as noted by Jaffe et al. (2000), however, the amount of funding to renewable R&D should increase due to the growth in demand for technologies from RES-E producers.

Attempts to attain the goal of spurring more momentum in renewable technology R&D through RES-E support schemes have their caveats. Literature including Nordhaus (2002) describes the issue of crowding-out of other R&D fields due to the financial influx in renewables research. Under the usual circumstances the decisions on R&D projects are made by market actors acting in a way that ensures the highest profit. However, when a market is artificially changed, the fields of research chosen under usual market conditions are abandoned and part of the funding moves to the fields endorsed by the support schemes. Previously preferred fields of research are now crowded-out, which might have negative consequences in the future.

The topic closely following renewable research is the diffusion of the RES-E technologies among electricity producers and manufacturers. The new or updated technologies need to be manufactured in a sufficient number of plants and used by sufficient number of producers around the country. Similarly to the previous case,

this task is met with a number of market imperfections standing in the way of the optimal diffusion of the renewable technologies. Due to knowledge spill-over, the early adopters of a technology have a disadvantage against the latter adopters. Through process of learning-by-doing, efficiency in production or use of a technology is gradually increasing, as the knowledge of the procedures related to the technology grows. The late adopters do not experience the costs related to this process due to the knowledge spill-over. Awareness of this fact discourages the producers and users from early adoption.

While the main target of RES-E support schemes in the EU is expressed as a mandatory percentage of electricity generated by renewable sources in the member states in year 2020 and beyond, the design of an optimal RES-E support schemes should fulfill several conditions and address several issues as well in order to ensure sufficient and sustainable inclusion of RES-E into the energy mix in future. From the viewpoint of a prospective RES-E investor and producer, it is crucial that the system (i) offers sufficient protection against risk stemming from electricity price volatility and (ii) ensures repayment of the initial investment in period that is comparable to other investment possibilities. Only system with sufficient protection and remuneration will (iii) attract a sufficient number of investments to fulfill the set goals and (iv) lead to the creation of a renewable electricity market that will continue to function after reaching the grid parity and phase out of support of RES-E. From the viewpoint of society the total costs related to operation of the system and remuneration of RES-E plant operators (v) need to be as low as possible and (vi) have to be dispensed among the final consumers, taxpayers and utilities in equal fashion, or in fashion that does not threaten the operations of any of these. Furthermore, the support systems (vii) ought to be robust enough to withstand unexpected changes in exogenous variables. In order to reach grid parity of the RES-E sources, the support scheme (viii) needs to spur research and development in relevant fields and (ix) has to induce large enough diffusion of the technologies.

The conditions under the points one, two, three, four and seven are referred to as the effectiveness requirement, point five as the efficiency requirement, point six as the equity requirement and points eight and nine as the research, development and diffusion requirement. While the effectiveness and efficiency requirements are in this paper tacked with use of a regression model, the remaining points are analyzed via literature review.

2.3 Explanation of support schemes and their theoretical assessment

Differentiation among the RES-E support schemes is usually based on whether the regulatory entity of a given state sets remuneration levels or the desired installed capacity of RES-E. In the first case the markets decide how much RES-E to install, in the second case the markets decide on the remuneration for a RES-E producer.

The first category of remuneration set by regulatory entity is represented by the Feed-in tariffs (FIT or tariff-based schemes), pre-set electricity prices that are paid to the producers by electricity utilities for an extended period of time, usually ten to twenty years. Couture & Gagnon (2010) further divide the FIT schemes to two categories, market independent and market dependent schemes.

The former category includes four types of schemes: plain fixed rate that is paid out to the RES-E producer for a limited number of years with an opt-out clause to sell the electricity on the market, should the market price grow larger than the FIT rate level; inflation adjusted fixed rate; front-end loaded model that pays out higher remuneration in the first years of life of the RES-E source and drops afterwards; and spot market gap model that lets the producers sell the electricity at market prices and remunerates them for the residual between this price and guaranteed FIT rate. The first three "standard" types differ mostly in the extent to which is the RES-E operator exposed to risk: The inflation adjusted rate is least risky and therefore most apt to induce fast RES-E growth, however, it may generate windfall profits for the operators in the long run, when the fixed costs are already paid for. On the other hand, while the operator is more exposed to the risk in the long run in the front-loaded system, the possibility of windfall profits is greatly reduced. The front-loaded system is currently the most widespread, active among others for some types of RES-E sources in Germany, in France or Switzerland. The gap model is, on the other hand, the only one that includes the RES-E producer in the electricity market. Furthermore, only the spot price is paid by the utility, while the premium is paid from the government budget. Therefore, the market distortion is significantly lower in comparison to other market independent schemes.

The latter category of market-dependent FIT schemes includes three types of schemes: a percentage of retail price model that is no longer in use due to overly high volatility and windfall profits brought into the system from the electricity market; a premium price model that remunerates the producers via a fixed premium paid on top of electricity market price; and a variable premium model that limits the premium

paid out to the producers through floors and ceilings. This is indeed an improvement over the regular fixed premium model, as the ceiling limits the possibility of windfall profits and the floor ensures a minimal level of remuneration and therefore reduces the amount of risk the producer is exposed to. The inclusion of the RES-E producer into the market, which is the main advantage of the premium model, is preserved in the variable premium model – the producers will actively seek to sell their production at the highest price and therefore when it is needed most. This system is currently in use in Spain.

The second category of RES-E support schemes consists of various types of certificate-based schemes (also called tradable green certificates, TGC, or Renewable Portfolio Standard) that are received by the RES-E producers for each unit of clean energy they produce on top of the electricity market price. The certificates could be either stashed or sold, either to electric utilities (that are obliged to hold certain percentage of the certificates with respect to their overall production or consumption) or to brokers. The Renewable Obligation scheme currently in use in the UK is an example of TGC-based scheme.

Remuneration of RES-E sources under TGC is based on the equalization of marginal costs among producers included in the system. Parry and Goulder (2008) among others describe this principle, often referred to as the equi-marginality principle, on market-based climate change mitigation systems. In such systems, each emission source has to present a sufficient number of emission allowances that covers its emissions. These allowances are traded on open market. The source can either buy allowances to cover its emissions or carry out adjustments that lower its emissions, based on which of the two options is cheaper. This leads to an equilibrium in which the sources, which are relatively more able to cut down emissions, do so up to the point where another adjustment costs more than an allowance, while relatively less able sources buy allowances up to the point where another allowance costs more than adjustment that would lead to lower emissions. Under equi-marginality the price of last abated unit of a pollutant is equal among all the emission sources included in the system.

Remuneration of RES-E sources under TGC is a variation of this principle. Electricity utilities are obliged to hold certain percentage of certificates related to the overall volume of the electricity they sell. The utilities buy the certificates on a certificate market. The price paid for a certificate is set at a point in the market where utility demand and producer supply of certificates encounter. Therefore, the price of a certificate is equal among all the RES-E sources included in the system. The marginal

RES-E source is exactly able to repay its per kW cost by price of one certificate (usually added to revenue from electricity sold for market price), sources that encounter lower costs generate profits, sources that encounter higher costs are unprofitable. When the requirement of percentage of certificates held by utilities grows, the demand on the certificate market makes the price of a certificate grow as well, allowing RES-E sources with steeper cost curves to be included as well. Due to the equi-marginality principle, the total cost of remuneration paid out to the producers is the lowest possible one.

Theoretical attributes of both support schemes change to some extent when one considers other simultaneously operating policies. Within the context of the EU, the EU ETS is the policy generating such interplay. A widespread agreement described by Fischer and Preonas (2010) states that policies that put a price on CO_2 are generally more efficient in reducing emissions than any RES-E support scheme. This argument builds upon a classical principle first described by Tinbergen (1952): in order to achieve the highest possible efficiency, one externality should be addressed by one measure. When two policies, in our case EU ETS and a RES-E support scheme, are aimed at one goal, CO_2 emission reduction, inefficiency lurks. However, Sijm (2005) argues for joint deployment of the two policies due to imperfect nature of the policies. Indeed, EU ETS can hardly be a one-size-fits-all solution and not all sectors can be included, while RES-E support schemes face externalities that are often non-resolvable by a sole scheme. Accounting for externalities and market imperfections not captured by EU ETS might be the sole function of RES-E schemes, as the inclusion of schemes does not generate any emission reduction over the level determined by EU ETS (Fischer and Preonas 2010).

While TGC-based schemes were favored in the early years of the debate on renewables, currently the most member states use variations of the FIT system. In order to review the change in opinions the theoretical properties and outcomes of usage of both systems need to be evaluated.

The two systems differ in level of fulfillment of the effectiveness requirement. A risk-averse investor evaluates investment opportunities based on net present value (NPV), which is an aggregate value of all income streams stemming from an investment that are discounted to present value and reduced by initial cost of investment. The final value is either negative, indicating a project that will not repay its initial investment, or positive. The repayment time is a period needed to exactly repay the initial investment and after which the project generates net profit. An investor orders available projects according to NPV or repayment time and chooses

the project offering highest NPV or lowest repayment time. Tariff-based support schemes offer more certainty in this respect, as the levels of remuneration to the RES-E producers are usually guaranteed for an extended period of time. Furthermore, the remuneration levels are often set at a value that offers repayment time similar to that of comparable investments in electricity generation projects. An investor is therefore able forecast future revenues stemming from an investment with adequate certainty. Furthermore, according to Parry and Goulder (2008), some categories of consumers, mostly households, tend to react poorly to energy efficiency savings, possibly due to their focus on a shorter time horizon. Feed-in tariffs can be set to account for this and offer relatively higher rates to the smallest investors.

The opposite is true for TGC-based schemes and to some extent also for some of the market dependent FIT schemes. An investor is not able to establish a reasonable outlook of future cash flows from the investment, on one hand due to more volatile difference of electricity price and variable costs compared to conventional electricity sources, and on other hand due to the difficulty in estimating of future developments of certificate prices, as markets for green certificates were established only recently and there is not enough knowledge on their behavior under different circumstances. Amundsen and Bergman (2010) show this in an example of the TGC scheme in Denmark, where quantity of electricity generated by wind power fluctuates by 25% between calmer and windier years. This fluctuation is translated into the TGC market, as the wind power plants always generate the maximal feasible electricity output dependent on the weather due to low variable costs. Under such circumstances any attempt to forecast future cash flows is extremely difficult.

Dong (2012) mentions certainty given to investors as a main advantage of FIT-based schemes over those based on TGC. Batlle et al. (2012) argues that while under TGC a producer is threatened by fluctuations in electricity market, FIT-based schemes in fact exclude the RES-E producers from the market and these then do not act on price signals. This issue is particularly severe in case of non-dispatchable RES-E sources such as wind and photovoltaic RES-E due to their low variable costs. However, it still holds that a major uncertainty in future development of cash flows of TGC-based schemes jeopardizes the goal of RES-E share in electricity generation, as investors may not be willing to realize projects with uncertain outcomes.

The two types of RES-E support systems differ in the costs needed to attain their goals. According to Böhringer and Rosendahl (2009), FIT-based schemes are cost-inefficient in attaining their goals. The remuneration of RES-E producers under FIT is based on decisions by regulatory bodies usually with repayment time in mind.

This results in FIT rates differing throughout the spectrum of supported RES-E technologies. If attaining s certain share of renewable electricity in the mix is the only renewable goal, this is indeed cost inefficient, as instead of a mix of RES-E sources with lowest per kW costs, the final RES-E output is composed of all the technologies selected by regulators, including those that would not be included under regular market conditions.

Optimally set FIT remuneration takes into account current levels and the possible development of various exogenous variables, including but not limited to, prices of equipment and components used in the creation and operation of a RES-E source, and changes in operating effectiveness of a source. However, in case of a sudden change in these underlying variables, the remuneration offered under the scheme generates NPV values, which are suddenly too high or low compared to other investment opportunities. This leads to oversubscription or insufficient involvement. The regulatory authority can respond to such a situation only to a limited extent, as the remuneration rates are often set for an extended period of time and can often only be changed within given band. Furthermore, there is a certain reaction time during which the new level of remuneration is decided upon and translated into legislation. This regulator lag leads to efficiency losses.

This is shown in the figure below using methodology devised by Campoccia et al. (2009). In the year 2009, the prices of solar modules used in photovoltaic power plants declined substantially due to the entry of new Chinese producers in the market. The remuneration rates set a year prior were lowered in order to lengthen the repayment time and slow down development of new PV electricity sources. However, the drop in prices of solar modules outweighed the decline of per kW remuneration rates, resulting in level of new PV that was larger than socially optimal and at a higher cost than expected.

Figure 1: Policy lag of reaction to sudden change of fixed costs
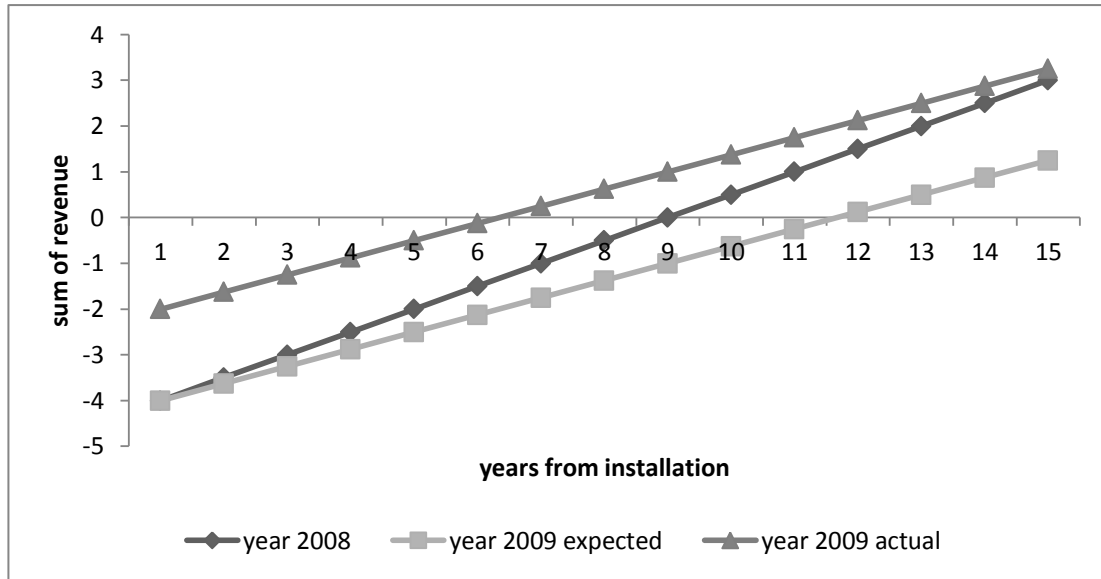
Source: own research

Tamás et al. (2010) criticizes FIT-based schemes on the grounds of their lack of effectiveness in attaining goals. Under TGC the costs of the scheme are borne by utilities that are required to hold number of certificates sufficient to cover certain percentage of their electricity output. This puts pressure on the utilities to switch from black, non-renewable energy to renewable sources. On the other hand, costs of FIT-based support schemes are mostly borne by rest of the economy, as the utilities often choose to internalize only a part of the cost and pass the rest through to the consumer. At the same time, the exposure of RES-E producers to developments on electricity market is either limited or non-existent, as the tariff is set by law and not influenced by market changes. This issue is even more severe when the tariffs are financed by a government budget or other non-market source, in such cases, the pressure on utilities to choose between green or black is lifted as well. This leads to overproduction, as both utilities and electricity producers are shielded from the market forces.

Equi-marginality theoretically ensures that TGC-based systems comply with the efficiency condition. However, inefficiency is sometimes brought into the system due to the heterogeneous nature of RES-E sources included in the system and the inclusion of inappropriate electricity sources. Verbruggen (2009) describes this issue in the case of waste combustion plants or wastewater treatment facilities included in

Flanders certificate system. When price of a certificate grows, less mature sources that encounter higher per kW costs and relatively steep cost curves, such as photovoltaic power plants, will be able to just repay their costs. However, should a mature technology with low costs and flat marginal cost curve be included in the system, a large part of remuneration could be captured by their operators.

Three types of RES-E sources are pictured in the figure below. While source A has a flat and relatively low marginal cost curve, sources B and C encounter higher and growing marginal costs. All of the three sources are only available in limited quantities. At point I, only operators of source A are able to repay their costs with remuneration they receive, represented by the area under the curve. At point II, the marginal operator of source B is able to exactly repay his or her costs, while other B operators under the point capture the rent stemming from their lower marginal costs. However, all the operators of type A sources are capturing excess profits that are not related to their activity. At point III, the B operators gain relatively small excess returns, while the A operators capture a large part of the remuneration. Setups similar to the one pictured bellow might lead to rent-seeking behavior by some investors who invest in sources that are usually mature and "dirtier" among the included sources.

Figure 2: Rents and excess profits under a TGC-based support scheme
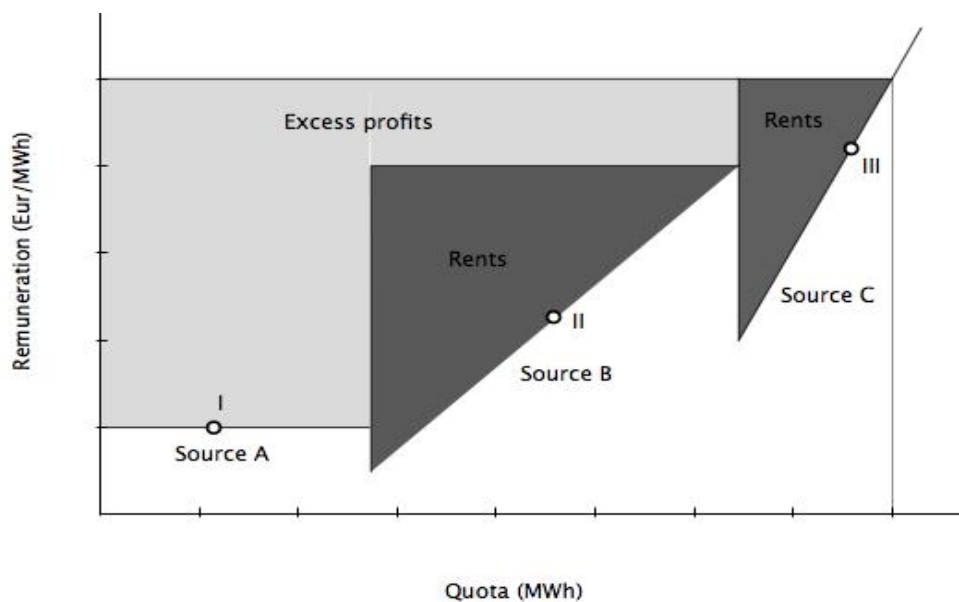
Source: Verbruggen (2008)

Bergek and Jacobsson (2010) confirm this point through analysis of the electricity market in Sweden. Most of the funds paid out under the Swedish TGC scheme went to facilities that were in function before start of the scheme. Between 2002 and 2008, only 2.5TWh out of 8.5TWh was generated in new sources, most of the remuneration was paid to pre-TGC biomass sources that increased their production under the scheme. In this case, most of the funding of the scheme was paid out to technologies generating excess profits. FIT-based support schemes are to some extent shielded from such adverse selection, as confirmed by del Río and Bleda (2012). While the more mature RES-E sources are often included into the schemes as well, the remuneration rates are usually based on repayment time and therefore offer lower rates to sources that have lower costs.

Regarding the efficiency condition, both types of support schemes could be negatively influenced by ill-devised settings of the schemes, be it the inclusion of unsuitable electricity sources among the supported RES-E sources or inappropriately set remuneration rates. As for the effectiveness condition, TGC-based systems are robust with respect to market change, ensuring stable market conditions without action of any other party, while the FIT systems offer higher level of security and certainty to RES-E producers, which in turn ensures their sufficient numbers.

The two systems differ substantially in the support they provide to R&D and the deployment of RES-E. Differentiated rates under FIT-based schemes remunerate all the RES-E technologies included into the scheme, while TGC schemes support only the least costly ones. TGC therefore induces only limited new funding into the more costly, less mature technologies. Bergek and Jacobsson (2010) depict this shortcoming through the theory of nursing and bridging markets. A new technology that is usually not able to compete with older technologies in terms of costs is shielded away from competition in a nursing market. In such market, this technology is promoted via pilot plants and substantial investments are made into its R&D. At a sufficient level of development the technology is partially exposed to competition at a bridging market. As development and deployment of the technology grows, the bridging market is transformed into regular market with minimal government regulation. TGC-based systems ignore nursing and bridging markets, exposing non-mature technologies to mature markets with level of support that, as confirmed in an analysis by Falconett and Nagasaka (2010), is not sufficient to allow these technologies to fully develop, and therefore, leads to lock-out of such technologies.

On the other hand, support to RES-E technologies under FIT-based schemes is a selective one. Inclusion of a technology and the level of its remuneration and

therefore of new funding to its R&D is based on the decision by a regulator. This leads to a situation where regulators picks technologies that are allowed to improve and grow in maturity vis-à-vis non-included technologies. Such technologies are then locked-out, not allowed to gain the same conditions for R&D as the included technologies have. According to Arthur (1989) "Technological paths might very much depend on initial conditions. As such, technologies having small short-term advantages may lock-in the technical basis of a society into technological choices that may have lesser long-term advantages than technologies that are locked-out." Alternatively, del Río (2012) and Mitchel and Connor (2004) indicate that the inclusion of RES-E installations into the mix under TGC-based schemes is in fact also favoring certain technologies, only this time the more developed technologies get picked rather than the less developed ones. Furthermore, del Río and Bleda (2012) suggest that greater deployment of immature technologies under tariff-based schemes triggers private R&D because of higher profit margins available to manufacturers of such technologies. From another point of view, the influx of funding into R&D could be simplified into progress ratio analysis: the type of scheme that attracts a greater capacity of a particular technology will also contribute more to decline of its cost. In any case, for best results a support scheme needs to be complemented with direct R&D support.

Lehr et al. (2008) explores the employment effect of RES-E inclusion through the analysis of the situation in Germany and assumes that the net employment effect of renewables is positive. This is conditional on the ability of German manufacturers to secure a sufficient section of the global market. Although 16% of worldwide turnover on RES-E system was made in Germany in 2004, their share of this market will decline with the expansion of the market in other countries. In contrast, according to Böhringer et al. (2012), this positive effect will rebound into a negative one, should the remuneration level be higher than only modest. Lehr et al. (2012) argues that a large domestic market leads to creation of a successful domestic industry that is then able to market most of its produce abroad, and illustrates this through the Spanish wind system producer Gamesa, which generates over 90% of its turnover outside of Spain. Indeed, while an established producer will be able to sell its product irrespective of the support of RES-E installations in its country of origin, survival of a new company is conditional on its domestic market and therefore on the number of installations at home. Finally, regarding the equity criterion, contrary to popular belief, the impact of RES-E support scheme on electricity prices was rather low. Moreno et al. (2012) surveyed the EU-27 countries to conclude that the impact of RES-E inclusion in the electricity generation mix creates only a modest increase in the price of electricity for households. However, the experiences of the countries

included in the analysis in this paper were varied, which will be described in further detail in the next chapter.

All in all, from the theoretical assessment it is clear that no RES-E support scheme is dominating the other in all the required conditions. A TGC-based scheme is more likely to fulfill the efficiency requirement, as the costs related to achieving the desired share of renewable electricity in the final mix are the lowest possible. However, regarding effectiveness or the ability of a scheme to attract the sufficient interest of investors, TGC underperforms due to its inability to offer an adequate level of certainty about future remunerations to the RES-E sources. When considered as second objective after attaining the desired share in the mix, R&D development is different under the two schemes as well. Influx of funds into R&D are very limited under TGC, as the system favors more mature technologies that would often be somewhat profitable even without any support scheme in place. In contrast, while able to spur research in less developed technologies, FIT-based schemes generate a substantial risk of picking the winners through administratively set remuneration rates, which could lead to future technology development that is not socially optimal. As put by Ringel (2006), nether FIT nor TGC have a significant edge over the other in their total performance.

2.4 Support schemes in Germany, United Kingdom and the Czech Republic

A theoretical comparison of the two main types of support scheme designs yields ambiguous results, therefore an analysis of empirical data is needed in order to assess the suitability of each given design. This analysis will be based on photovoltaic and wind RES-E data from three countries: Germany, which has well-implemented FIT-based support scheme that is frequently used as a basis of comparison with other countries' schemes, the United Kingdom as a representative country for TGC-based support schemes (and a late adopter of a tariff-based scheme for small sources) and the Czech Republic, where the RES-E support scheme went through rocky patch. While Germany and the UK had RES-E support schemes in place before introduction of the RES-E directive, the Czech support scheme was introduced as a consequence of the RES-E directive.

The German RES-E Support Scheme

According to German NREAP (BREG 2010) submitted to the EC in 2010 in accordance with the Renewable energy directive (2009/28/EC) the country is bound to reach a 18% share of renewable energy in gross total consumption by 2020, which translates into 38.6% of RES-E in electricity consumption.

The generation of electricity from renewable sources began to be supported in Germany in 1970's, the first support scheme was implemented in 1989. In 1991 fixed tariffs for wind energy producers were implemented via the Feed-in law (StrEG). The first version of current renewable energy law (Erneuerbare Energie Gesetz - EEG) was introduced in the year 2000 and set levels of remuneration paid to RES-E installations. Currently supported technologies include those based on solar radiation (solar photovoltaic and solar thermal), wind, geothermal energy, biomass, landfill, sewage and mine gasses and hydropower, as well as the co-generation of electricity and heat.

The law gets updated annually with new remuneration rates, which reflect changes in the underlying variables, such as change in fixed costs of supported technologies or installed capacity. If not stated otherwise, the rates set by EEG are subject to an annual decrease for installations that are connected to the grid in given year. That means that while an installation has level of remuneration fixed for its whole life, remuneration for a similar installation connected to the grid a year later will be lower. Furthermore, the tariffs differ with respect to scale of an installation, technologies used and requirements fulfilled. For example, according to EEG 2011, a small roof-mounted photovoltaic installation with capacity under 30kWp was entitled to receive 0.29 Euro per kWh, while a ground-mounted installation was entitled to 0.22 Euro per kWh, regardless of its size. Similarly, a biomass installation is entitled to extra 2 Eurocents per kWh if it fulfills criteria stated in an EEG annex on innovative technologies.

German parliament has been reasonably fast in amending the law outside of the one year cycle, as the situation demands it. In 2010 the German photovoltaic market began to overheat, with installed capacity ahead of what was planned in German NREAP. As a reaction the law was amended and the rates dropped for installations connected to the grid after the end of June. By the end of 2011 capacity of RES-E reached 66.5 GW, which means that Germany was able to outrun trajectory of installed capacity of RES-E by almost 10%, Most of this growth was however caused by surge in photovoltaic RES-E, therefore further substantial reductions for PV were introduced in 2012.

Figure 3: Wind and photovoltaic RES-E in Germany
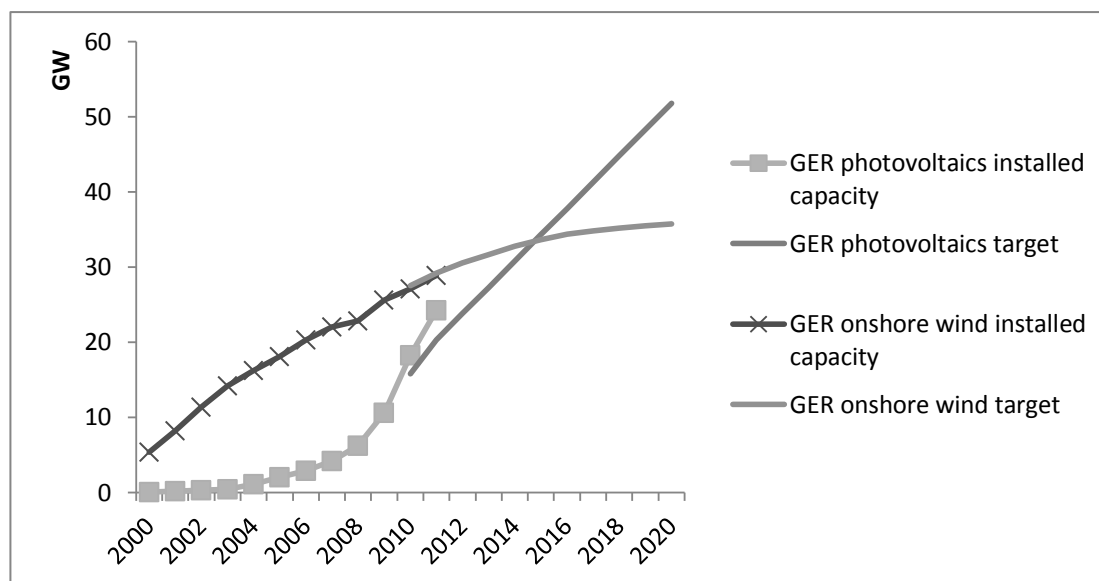
Source: BREG (2010), IDU (2012)

The remuneration is paid out by grid operators, who are legally obliged to provide access to any RES-E source that complies with regulations. The grid operators are free to decide what portion of the costs to pass on to the final consumer.

Findings of an older paper by Traber and Kemfert (2007) that takes into account emission trading corresponding with the notion that the equity impact of RES-E support is only modest, as the consumer price of electricity in Germany should increase by 0.1 euro cent per kilowatt hour due to inclusion of RES-E. However, according to a more recent paper (Traber et al., 2011) the strong growth of the German RES-E market increased costs borne by final consumers. In 2011, the EEG apportionment in household electricity price amounted to 3.53 euro cents per kilowatt hour, or approximately one sixth of the final price, inclusive of tax. However, support for RES-E is expected to be offset by a large extent by the decline in electricity market price due to the inclusion of renewables before 2020, therefore the expected increase of the apportionment is only modest.

The growth in German stock of RES-E was mostly in line with what was planned, which is why German RES-E scheme is considered to be a baseline against which other countries compare. Some examples of this include, but are not limited to Held et al. (2007), who compares Germany, Spain and Slovenia; Wüstenhagen and Bilharz (2006), who use the German example as a guideline for other countries' RES-E markets development; Büsgen and Dürrschmidt (2009), who describe the German RES-E scheme as "exceptionally successful instrument for the promotion of

renewable energies;" Mabee et al. (2012), who uses the German scheme as an example for a similar scheme in Ontario, Lipp (2007) finds tariff based schemes of Germany and Denmark sharply better than the certificate-based scheme of the UK.

The RES-E Support Scheme of the United Kingdom

The first large scheme aimed at the promotion of renewable energy in the United Kingdom was the Non-fossil fuel obligation (NFFO) system in the early 1990's. Under NFFO renewable energy and nuclear energy generators were awarded a fixed price per kWh of electricity produced, which was financed by a tax on electricity consumption. The last group of installations was included into the system in 1998. NFFO was not overly successful, out of 933 projects with capacity of 3.6 GW that were contracted only 441 projects with capacity of 1.1 GW were commissioned as of the first quarter of 2004 (Wood and Dow 2011).

In order to introduce more renewable energy into the mix new TGC-based policy was introduced in 2002. Under the Renewable obligation scheme (RO) each RES-E generator was awarded one Renewable obligation certificate (ROC) per MWh of electricity produced. Electricity distributors were supposed to cover certain share of their electricity sales, starting at 3% in the April 2002 – March 2003 period and currently set at 15.8% (or 15.8 ROCs per 100 MWh) for period ending in March 2013, by an appropriate number of ROCs. The generators were allowed to sell their ROCs either directly to distributors or to brokers. In the case where a distributor is not able to present sufficient number of ROCs, the difference between their actual number and the requirement is paid for at the level of a buy-out price set by the market regulator. Simply, the buy-out price is in essence a ceiling for price of single ROC. Funds generated from the buy-outs were then paid back to distributors with respect to the share of their requirement fulfilled by buying ROCs from producers.

Shortly after its introduction the performance of the system began to be criticized. Pöyry (2006) describes one of the most notable caveats of the system. The closer the market is to fulfilling the required share of ROCs, the lower the demand for them and therefore the lower their price. After fulfilling the goal price of one ROC quickly falls to zero, which threatens profitability of RES-E projects. Another attribute of the scheme that greatly increases risk is the absence of a law that would ensure access of RES-E projects to the grid. Every investor therefore has to find a distributor that is willing to buy its electricity.

Figure 4: Decline in price of ROC with percentage of RES-E target fulfilled
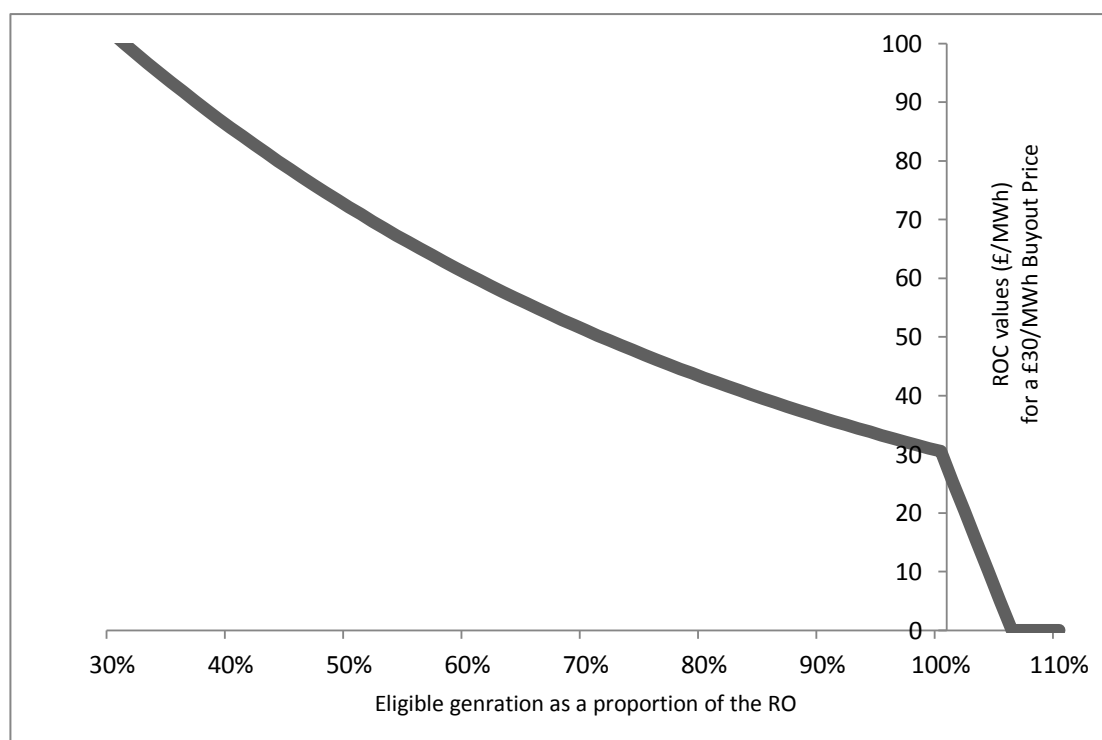
Source: Pöyry (2006)

The higher risks are reflected in the different type of investor who enters the RES-E market. To a degree higher than in other markets, renewable projects in the UK are undertaken by large utilities that are able to internalize related risks, as noted by Gross et al. (2007). Indeed, size of a typical project varies accordingly, while the average size of a grid-connected onshore wind installation in Germany by the end of 2011 was equal to 1.35 MW, average size of such installation in the UK reached 5MW. Woodman and Mitchell (2011) add that transaction costs of the system related to trading with ROCs and finding a market for produced electricity are prohibitory for many small generators. Wood and Dow (2011) criticize the scheme on the basis of the technologies it stimulates. The RO scheme favors only the least-cost renewables, landfill gas and onshore wind, the application process takes rather long time and only a fourth of the intended projects are allowed to be realized. Furthermore, most of the permitted wind installations were built in Scotland, which creates an uneven pressure on the grid (Woodman and Mitchell 2011).

In order to improve its performance the scheme was amended gradually. The occurrence of the "cliff edge", the substantial drop of ROC price after fulfilling the renewable goal of the distributors, should be solved by a different targeting of desired share, which was introduced in 2009 (or rather the period of April 2009 to March

2010). From this period, the goal is set as expected generation for given year in percent increased by 8% to 10%. This should introduce more stability of the price and push the distributors away from trying to capitalize on the buy-out fund. RES-E source banding was introduced at the same time. Installations built in this and following years will receive differentiated number of ROCs for electricity they produce; from 0.25 ROC per MWh produced in an installation using landfill gas to two ROCs per MWh from offshore wind installations. While encouraging investments into less developed and more capital-intensive technologies, this also represents "winner-picking" behavior mentioned in relation to tariff-based schemes. There is no differentiation among sizes of a given type of installation, which means that economy of scale favoring large investors remains in place. Furthermore, under this modification it is not certain anymore what the final capacity of the installed RES-E will be. Nevertheless, banding seems to have improved performance of the RO scheme to certain extent (Buckman 2011).

Perhaps most importantly, inflation-indexed feed-in tariffs were introduced for installations bellow 5 MW (UK FIT). Since April 2010 both existing and new installation can opt-out from ROC-based scheme and receive FIT rates instead. The impact of the introduction of the FIT-based scheme for small sources was substantial, at least in the case of photovoltaic generators. By the end of the 2011-2012 period, around 4 MW of photovoltaic capacity was installed in the UK under the RO scheme. Conversely, during the two years after introduction, FIT-based scheme yielded over one GW of installed photovoltaic capacity. However, in the case of wind, the result was quite different; the impact of FIT on wind energy capacity was marginal. Based on analysis of returns to a PV installation Cherrington et al. (2013) describes UK FIT as a success, despite frequent changes in remuneration rates. The UK FIT should result in installations that cover 2% of electricity demand by 2020 (DECC 2009). According to Walker (2012) this target is attainable in case electricity prices will grow faster than in the past.

Figure 5: Wind and photovoltaic RES-E in the UK
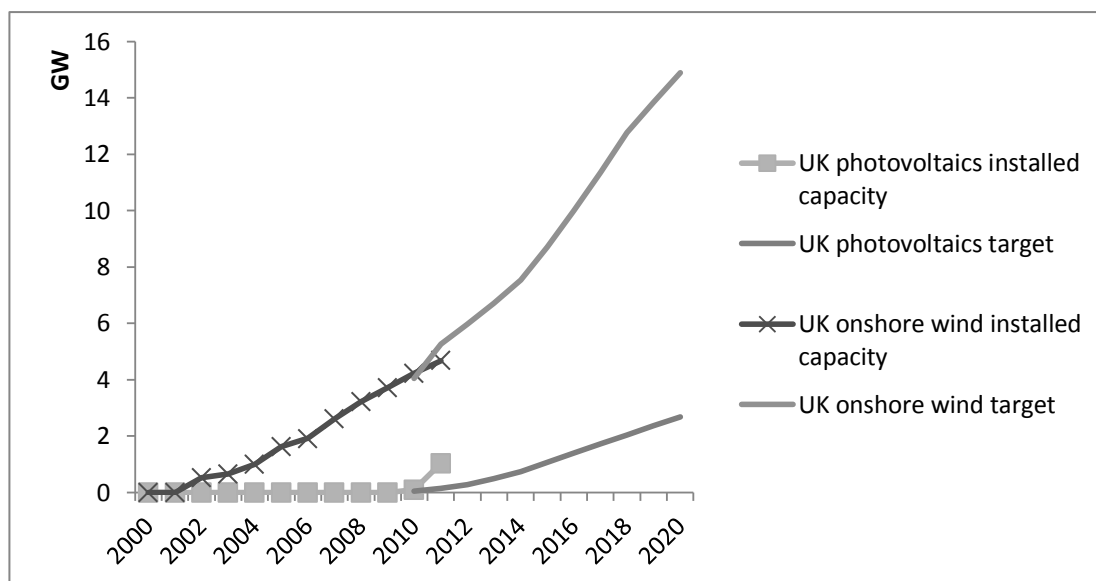
Source: DECC (2010b), REF (2012)

Finally, the equity impact of RES-E inclusion is fairly low, but this is mainly due to the low capacity of RES-E installed. According to a study by DECC (2010a) the share of RES-E support on an average household electricity bill in the UK will grow from 4.7% in 2010 to 17.5% (or 19.2% including the cost of small installation support under UK FIT scheme) in 2020. In case of non-domestic retail electricity price the share will grow from 5.3% to 23.3% (or 25.6% with inclusion of FIT). This is well above the values of the German case.

The RES-E Support Scheme of the Czech Republic

In the Czech Republic the support scheme for renewable energy generation was introduced by law 180/2005 Sb. on support of electricity generation from renewable energy sources (PSP 2005). The law established two modes of RES-E support, inflation-indexed flat tariffs and green bonuses that are paid on top of revenues gained from sale of electricity on market. The tariff levels are set each year by the market regulator (Energetický Regulační Úřad, ERÚ), who was originally allowed to set remuneration rates at a maximally 5% lower level compared to those of the previous year.

The inclusion of RES-E into the energy mix was a rather controversial affair in the Czech Republic, especially in case of PV. Both in Germany and in the UK, different tariffs were paid out to various PV systems according to their size since start

of their FIT schemes, while in the Czech Republic, exact opposite held true during the photovoltaic boom of 2009 and 2010. First substantial differentiation among installation sizes occurred as late as 2011, because prior to that the regulator was restricted by the 5% clause. The law was amended as late as 2010, with its implementation starting in 2011. This approach resulted in a mix of photovoltaic RES-E that is strongly aligned towards large, brownfield installations.

Figure 6: Share of different size categories on total installed photovoltaic capacity, end of 2011
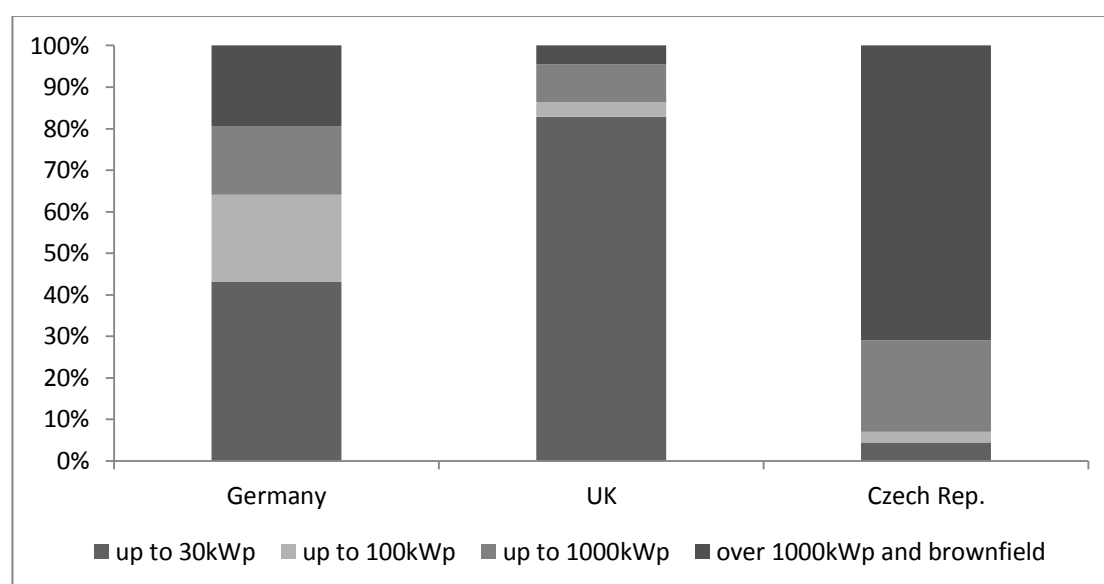
Source: IDU (2012), REF (2012), ERÚ (2012a)

What followed brings to mind the remark by Battle et al. (2012) that unstable political and institutional framework can destabilize a FIT-based market. Due to the explosion of the PV market, a full halt for photovoltaic and wind installations was introduced in 2011. In November 2011 Czech parliament approved an amendment that introduced a 26% tax on tariffs for photovoltaic installations built in 2009 and 2010 that will be paid from 2011 to 2013 and revoked tax breaks for these installations. Since 2012, façade- and roof-based installations under 30kWp are allowed to connect to the grid, however, it is not entirely sure for how long they will continue to be supported. Conversely, the current level of installed capacity of wind energy is lower than the NREAP targets. According to a press release of ERÚ from beginning of 2012, full halt of remuneration of RES-E producers is expected to take place soon (ERÚ 2012b). While roughly similar to the German support scheme, the impact of Czech support scheme on the RES-E market brings to mind note by Jenner et al. (2013) that the "act of implementing a poorly designed policy is not necessarily better than having no policy at all."

Figure 7: Wind and photovoltaic RES-E in the Czech Republic
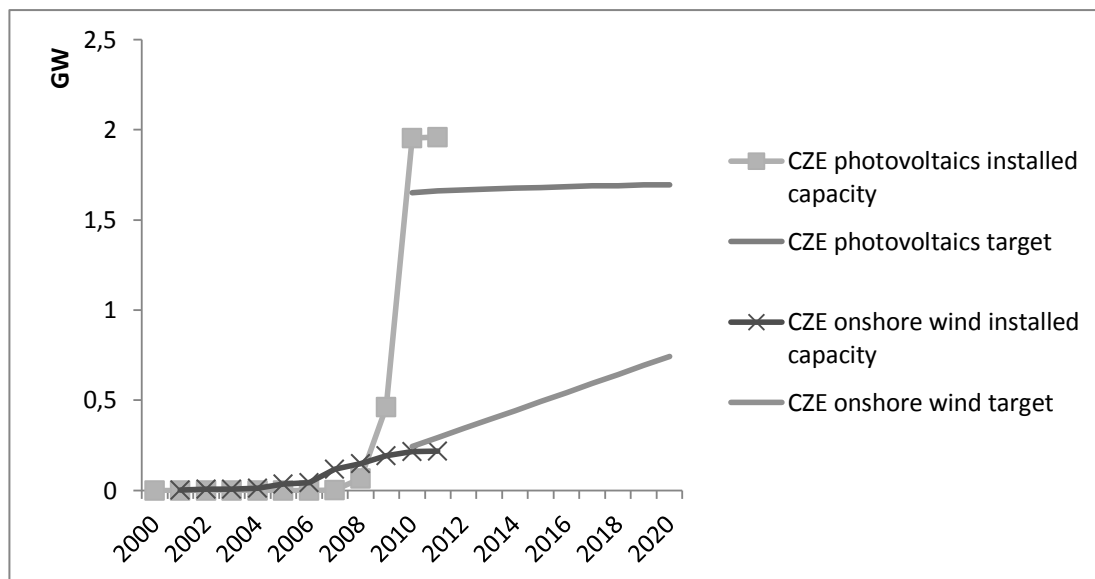
Source: ERÚ (2012a), MPO (2010)

Regarding the equity impacts of RES-E support, Bechník (2012) calculated the cost of support of RES-E generation amounts to 0.65 CZK (roughly 2.6 euro cents) per kilowatt hour, which translates into approximately 16% of household per kWh price. While not negligible, the impact of RES-E inclusion is on par with the German market.

The following chapter is dedicated to the creation of a framework to analyze the support schemes within the three countries and a first discussion of the results.

3 Data

In order to assess the performance of support schemes in Germany (GER), the UK and Czech Republic (CR), an analysis of the dependence of the installed capacity of a given renewable energy source on returns to its owners was carried out. The following three combinations of dependent and independent variables were used:

- the regression of newly installed capacity or new count of wind RES-E sources on IRR of those sources in GER, UK and CR, based on bi-yearly data from 2004 to 2011;

- the regression of newly installed capacity or new count of photovoltaic RES-E sources on NPV of those sources in GER and CR, based on yearly data from 1995 to 2011;

- the regression of newly installed capacity or new count of photovoltaic RES-E sources on NPV of those sources in GER and CR, based on monthly data from 2006 to 2011.

In the following paragraphs the approach to return (the independent variable) is outlined. The description then continues with the data used (dependent variable) and a characterization of the econometric model.

3.1 Return to an installation

Data on the returns of wind installations were taken from the Bloomberg new energy finance database (BNEF, Bloomberg 2012), which provides returns to wind energy projects connected to the grid in the period from 2004 to 2011. The setup of the BNEF wind model is as follows.

Firstly, data on probability distribution of wind speed at a given spot is derived from a third-party wind speed database that contains hourly samples for a ten year period of time. The curve is translated into a power curve for a given installation with use of the BNEF wind turbine price index and accounting for efficiency losses. Annual electricity generation of given installation is then derived, with respect to efficiency with which is given turbine able to convert power of wind into electrical energy. The value is reported at 98% technical availability level, with the residual 2% reserved for operation and maintenance.

Secondly, the costs consisting of capital expenditure (CAPEX) and operating expenditure (OPEX) are derived. The value of CAPEX breaks down into three components: turbine equipment cost (68%), costs related to balance of plant (such as control and grid connection costs, 30%), and development costs (consisting of administration, planning and similar costs, 2%). OPEX costs are based on fixed per output (megawatt MW) costs and variable per unit of generation (megawatt hour MWh) costs are adjusted for inflation.

Thirdly, the revenue side of given project is assessed based on the type of tariff currently in use and its parameters, such as the existence of inflation linking or duration of scheme and including other variables that influence revenues, such as forecasts of electricity price in given country. For example, in Germany, the revenue stream of a wind energy project consists of FIT tariff for the first 20 years of operation and the electricity price for last five years, while in the UK the revenue stream of a project consists of the TGC price and the electricity price throughout its whole life.

Finally, the financing part of the model brings together the inputs in order to calculate the cash flows of a given installation. The following assumptions on the life of a project are taken: a project is developed for two years, constructed in one year and is active for 20 years. Part of the capital expenditure is expected to be financed by a senior, long-term loan that can be followed by subordinated debt after end of construction. Capital structure of financing of given project is given by a debt service coverage ratio (DSCR).

$$DSCR = \frac{EBITDA}{loan_r + \frac{loan_p}{1 - tx}} \tag{1}$$

Where:
- EBITDA are earnings before interest, tax, depreciation and amortization in given year;
- $loan_r$ is the interest portion of debt paid in given year;
- $loan_p$ is the principal portion of debt paid in given year; and
- tx is the tax rate in a given year.

A portion of the project debt financing is optimized given a DSCR of 1.2, the cost of debt is assumed at a level of swap rate corresponding to the length of the loan tenor. Depreciation is assumed in accordance with the laws of a given country, along with carrying a net loss forward for the purpose of tax liability.

The resulting after-tax cash flows are plugged into a NPV equation, specified as follows.

$$NPV = -Inv + \sum_{t=1}^{N} \frac{CF_t}{(1+r)^t} \qquad (2)$$

Where:
- Inv is a portion of CAPEX financed from own equity;
- CF_t are after-tax cash flows in year t;
- r is the discount rate; and
- N is the life of a given installation.

In the model the discount rate is assumed to be equal to 0.1 across all the installations. IRR (internal rate of return) is defined as the value of r for which the NPV equals 0.

Originally, the BNEF database was searched for data on wind installations connected to the grid during the period of 2004 to 2011 in Germany, the UK and the CR. Values of NPV at 10% discount rate and IRR were grouped into groups according to year and country, and the median installation was found for each of these groups. However, this approach yielded an incomplete dataset for the CR. For Germany, data on 1450 installations were found in the database, while for the UK and CR, only 193 and 29 installations were available, respectively. A different approach was therefore used: A "median spot", a coordinate with an installation whose yearly generation of electricity per year was a median of all the installations, was selected. An artificial installation with these parameters was then constructed, based on an industry-standard turbine (Vestas V80 80m/2m), and moved around spatially (country-dependent inputs such as remuneration level and electricity price were switched between GER, UK and CR) and in time (2004 to 2011, half-year steps). This approach yielded series of IRRs specific for given country and year.

Unlike the case of wind, there is no database of returns for photovoltaic installations; the returns were instead modeled, using a methodology similar to that of BNEF wind. Four size classes of installations were assumed across the countries: a small installation class for installations under 30 kilowatt peak capacity; a medium class for installations over 30 and under 100 kilowatt peak capacity; a large class for installations over 100 kilowatt peak and under one megawatt peak installed capacity; and a brownfield installation class for installations over one megawatt peak capacity. The first class comprises mostly of roof- and façade-mounted installations of

households, the second class is similar but larger, the third class contains large installations on roofs and facades of objects such as market and administrative centers, and the fourth class contains installations built on ground that consume only a small fraction of electricity produced and feeds most of it into the grid. The result of this approach is a series of NPV, with each NPV specific for an installation built in given year (model 2) or month (models 3 and 4) and its installation class. Roof-mounted installations above 1 megawatt peak and brownfield installations are assumed to be together in one class.

Firstly, data on the electricity produced per year and per one kilowatt peak of a photovoltaic system was collected from the PVGIS application of Institute for Energy and Transport of European Commission (JRC 2012). Ten samples were taken for each region of GER, UK and CZE, the average results from the regions in given country were then weighted according to the total installed capacity of that region compared to the capacity in the country in 2011. System losses of 10% were assumed. The value was then adjusted for the lower efficiency of panels installed in earlier years.

Secondly, the development of CAPEX costs per unit of output was devised, based on the price index of BSW Solar (BSW 2012), and adjusted for large sources in order to capture the economies of scale – ground-mounted installations were assumed to have costs 10% lower than other installations. The OPEX was assumed at 2% per annum.

Thirdly, revenue streams per kilowatt peak of given size of installation were calculated. For Germany and both yearly and monthly data, feed-in tariffs were the sole revenue stream for the first twenty years of the life of an installation, while in the last five years, electricity was assumed to be sold for market prices. Same approach was taken in the case of the Czech Republic. The investors were assumed to opt for a flat tariff rather than a green bonus.

Finally, for financing, the maximum allowed share of debt was selected according to the DSCR criterion described above and capped at 80% of the total capital requirement. Only one tranche of long-term debt with a 15 year maturity was assumed, as this was closest to the actual treatment of debt in the BNEF model. Straight-line depreciation over the life of an installation was assumed, as well as the payment of taxes on revenues according to the tax rate of given country.

The NPV was devised by discounting cash flows from an installation at a country-specific discount rate, because such discounts rates contain all relevant

information on the specifics of capital market. Allowing the cash flows to be discounted by country-specific discount rate therefore takes into account regional specifics of the respective markets and allows us to compare among those.

The country-specific discount rate is composed of the cost of equity and the cost of debt. The cost of equity was constructed as follows: the risk-free rate was estimated at a level of return of 10 year government bonds as a yearly average. For the Czech Republic, such bonds were not available prior to the year 2000, therefore government bonds with a shorter maturity were used. Market risk was based on the arithmetic average of the difference between returns of S&P 500 stock and US government bonds since 1926, as reported by Ibbotson SBBI Valuation Yearbook (Ibbotson 2012). The Czech market risk premium was assumed at levels reported by professor Aswath Damodaran (Damodaran 2012), which were estimated based on the excess return of index of stocks that have same rating as a given country. No risk premium was assumed for Germany, as it is a mature market with government bonds rated at the AAA level. The unlevered beta of renewable energy market was based on the market data of traded companies that generate electricity from renewable sources, as reported by Bloomberg (2012). The value of beta was further adjusted for market convergence, re-levered and adjusted for tax rate. The variables were brought together to form the cost of equity as described in the following two equations.

$$c_e = r_f + \beta * \left(r_m - r_f \right) + r_c \tag{3}$$

$$\beta = 0.635 \beta_{ul} \left(1 + (1 - tx) \frac{D}{E} \right) + 0.371 \tag{4}$$

Where:
- r_f is the risk-free rate;
- β is the levered Beta;
- r_m is the market risk;
- r_c is the country risk premium;
- β_{ul} is the unlevered Beta;
- tx is the tax rate valid for s given country and year; and
- $\frac{D}{E}$ is the share of debt to equity valid for s given installation size, country and year.

The cost of debt was constructed as follows. The variable part of the cost of debt was estimated at the level of 15 year fixed vs. 6 months float (interbank offer rate) swap in given currency. If a swap rate was not available, an interbank offer rate

(LIBOR, PRIBOR, EURIBOR/BBA LIBOR) was used instead. This approach was taken, because most of debts are based on interbank rates, however, these vary in time, therefore a swap was used as a measure for the investor to fix them. A fixed margin of 2% was added on top of a given rate.

The discount rate specific for each year, country and size category of installations was derived as described in following equation.

$$WACC = \frac{E}{D + E} r_e + \frac{D}{D + E} r_d \tag{5}$$

Where r_d is the cost of debt specified as r_d = swap rate + fixed margin.

For more information on the data used in the model, please see Appendices A and B.

3.2 Dataset

The data on installed capacities and counts of the RES-E (the dependent variable) were collected from several sources. Data on German installations were downloaded from the information platform of German distribution networks (IDU 2012) for data up to year 2011. For the UK, data on installations registered under the RO scheme were obtained from the Renewable Energy Foundation (REF 2012), the dataset on installations under FIT scheme was downloaded from Ofgem (2012).

For the Czech Republic, no public source of data that was completely trustworthy was available at the time of completion of this paper. Data on photovoltaic installations currently available on web pages of ERÚ (ERÚ 2012c) are inconsistent with the data previously reported by ERÚ and with data provided by third party (Elektrarny.pro, 2012). The dataset on Czech photovoltaic installations is therefore a combination of data obtained from the second mentioned source (1995 to mid-2011) and from the ERÚ webpages (ERÚ 2012c) for data from the middle of 2011 to September 2012. Data on wind energy projects were gathered from the Czech Wind Energy Association webpages (ČSVE 2012).

3.3 Wind installations

In order to account for differences between tariff- and certificate-based schemes an estimation is provided of the effect of returns from wind energy installations in a form of IRR on the installed capacity or the number of installations, respectively,

both expressed per million of inhabitants, in the three countries and based on half-yearly data from 2004 to 2011.[2]

Any attempt to treat the impact of support schemes on investor willingness to invest in wind energy with econometrics is futile, as there is only very general pattern connecting IRR of a wind energy project with installed capacity. The most relevant reason for that is that, unlike photovoltaic sources, a wind energy installation takes longer time to be completed, therefore an investor does not react to return of a project but rather on his or hers expectation on the return of a project in two to three years. Making such an expectation is not trivial, with PV, the installation costs are almost monotonically decreasing in time, this does not hold true for wind energy. This complicates any attempt by an investor to forecast fixed costs of an installation year or more ahead.

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[2] Please note that due to the unavailability of half-yearly data for the Czech Republic, yearly values are used instead.

Figure 8: Number of installations (upper) and installed capacity in MW (lower) of wind RES-E to IRR per installation
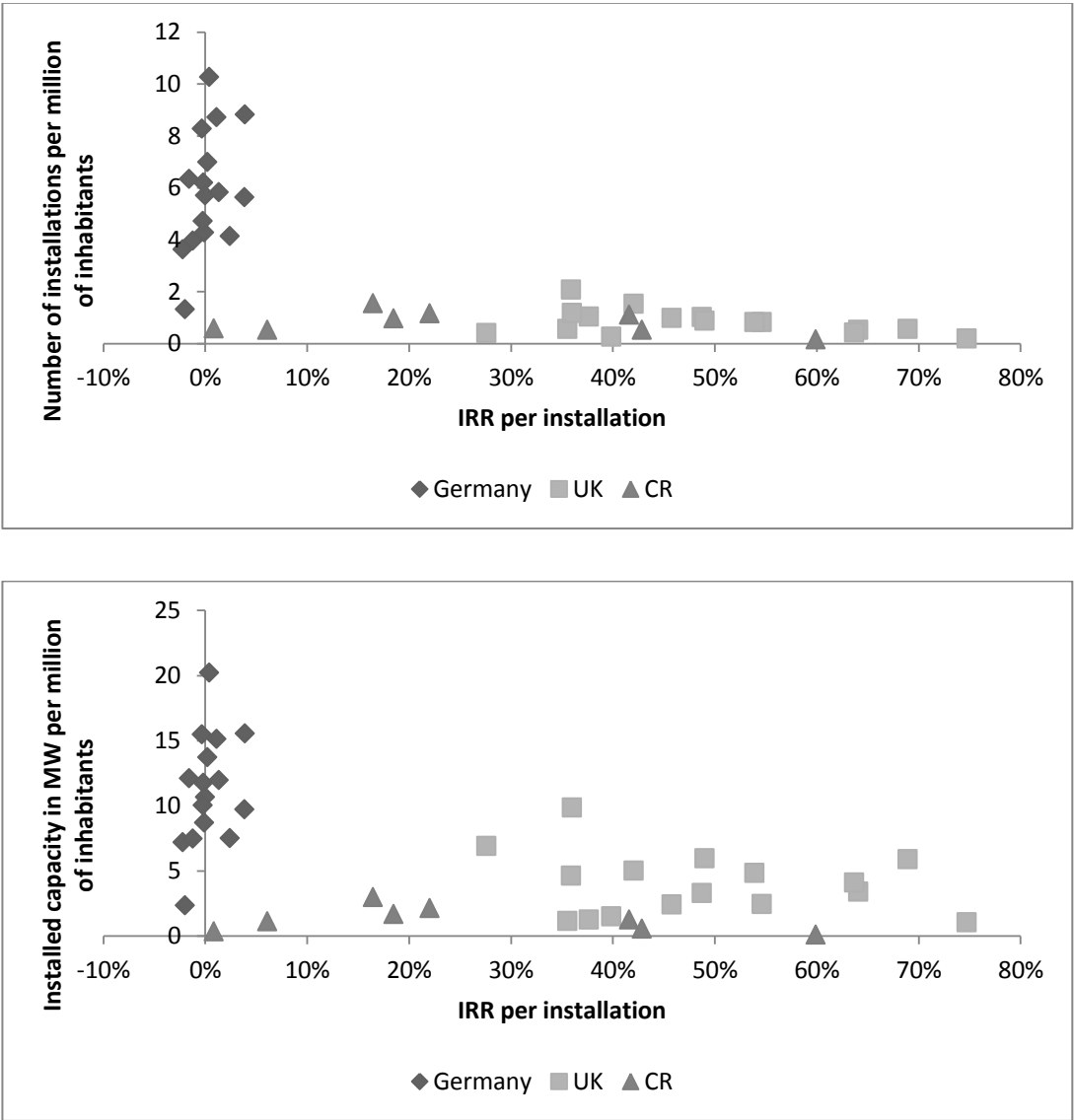
Sources: Bloomberg (2012), BNetzA (2012), ČSVE (2012), REF (2012), own research

While there is no analytical basis on which the impact of different scheme setups on installed wind count and capacity could be described, visual analysis of plotted values shows that the German scheme was able to attract more wind RES-E in terms of both count and capacity than those of its peers. Furthermore, capacity per installation in the UK is substantially higher than in either Germany or Czech Republic. The case of wind is discussed in more detail in the sixth chapter of this thesis.

4   The model

4.1   Specification of the econometric model for PV

A simple econometric model was used to estimate a relationship between number or capacity of PV RES-E installations respectively (the dependent variable) and financial return to the investor (the independent variable). The model partially follows a conceptual model of Wand & Leuthold (2011) and van Benthem et al. (2008) and can be described as follows.[3]

$$\ln(cap) = \alpha + \beta.return + \delta.category\ variable + \varepsilon \qquad (6)$$

Where:
- The cap is either the capacity in MWp installed per million of inhabitants or the number of installations per million of inhabitants in a given size class and year or month;
- the category vector variable describes the size classes, time periods or countries, based on specification of given model; and
- the return is NPV or IRR of given installation class size in a given year or month;
- coefficients alpha, beta, delta and gamma need to be estimated.

Variations of this setup are used across all the models in this paper. Due to the specification of the regression equation, the outputs are interpreted as percent change in dependent variable with unit change in independent variable. The constant and the category variable shift the regression curve. In all the cases, standard tests available in STATA were performed in order to verify the linear regression assumptions. Normality assumption was inspected via Shapiro-Wilk test, homoskedascity was tested via a combination of Breusch-Pagan test for heteroskedascity, Cameron & Trivedi decomposition and visual analysis of residuals plot. Inclusion of all relevant variables was tested by the Ramsey RESET test.

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[3] STATA statistical package used in computations works with a category variable instead of set of dummies, this does not change the results.

The first model examines the effect of financial performance on photovoltaic installations in Germany and the Czech Republic. Specifically, the relationship between returns of investors and the number or capacity of PV installations is estimated for different size classes (as specified in chapter 3.1) and for each of the two countries in the years 1995 to 2011.[4]

In this case as well as in all the following models it is assumed that the coefficient beta does not vary across the size classes (models 1 and 3) or time periods (model 2). While this restriction might bias the results to a certain extent, it is a necessary precondition to compare among different installation types and different years.

Two variations of the first model are included, in the first one the zero values (no installations at a given level of return) were replaced by small non-zero values, in the second those values were dropped. While the former approach is more commonly used in similar empirical work, the latter approach is generally assumed to be more appropriate (Young and Young 1975). Both of the approaches have their drawbacks: while the inclusion of zero values skews the regression curve towards lower effect, dropping the zero observations presents an exclusion of an investor's decision not to invest. Differences in results between both variations of the model are discussed bellow.

The second and third model focuses on the effect of the financial performance when controlling specifically for the time period (model 2) or for the size class of photovoltaic installations (model 3). The model 2 controls for the time period and is estimated separately for the four classes defined by the installation size in order to assess time dynamics of diffusion of those installations, whereas the model 3 controls for the differences among the size classes by by estimations separately made for several periods. The model model needs to be estimated for the differences among different installation types and different years separately, as accounting for both of these differences at the same time would require too many dummy variables compared to size of the available dataset.

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[4] In case of the Czech Republic the period ends in 2010, as the market was shut down temporarily in 2011.

The second model employs data from Germany (2006-2011) and the Czech Republic (2008-2010).[5] The data used in third model cover the period of 2008 to 2011 (Germany) and the period of 2008 to 2010 (Czech Republic). For Germany, half-year periods are assumed, as the investor activity peaks in June (the month before the sunniest part of a year) and December (investors try to connect their installations to the grid before the end of the year in order to achieve a level of tariff valid for that year). In the Czech market only the second tendency is noticeable, one-year periods are therefore assumed there. Furthermore, two outliers were dropped for Germany (PV2 and PV3 in June 2009) due to being excessively influenced by investors from the previous year's December who did not manage to connect their installations to the grid while the tariff rates were more favorable.

4.2 Model 1 – Photovoltaic installations, yearly regression

The first model comparest PV RES-E markets in Germany and the Czech Republic by using yearly data for 1995 to 2011 period in case of the former and 1995 to 2010 in case of the latter. Firstly, a model of installed capacity and number of installations in given year was performed with zero values of the dependent variable replaced by small nonnegative values. The model is summed up in following table. Please note that interpretation of these values is non-trivial, as natural logarithms of dependent value were taken into regression. For the regression outputs in more detail please see Annex 3.

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[5] The difference between the periods is a result of the nonexistence of a photovoltaic market in the Czech Republic in 2006 and 2007 and the regulator's decision to cease supporting renewable energy in 2011. In the German case, the year 2010 is divided into two half-year periods, because the conditions of the scheme changed greatly in the middle of the year, destabilizing investor reactions to a large extent.

Table 1: Yearly regression of number and capacity of photovoltaic RES-E projects on their NPV, zero values changed to small non-zero ones

	Coefficient β	Intercept pv1 e^{α}	Intercept difference between pv2 and pv1 $e^{\delta12}$	Intercept difference between pv3 and pv1 $e^{\delta13}$	Intercept difference between pv4 and pv1 $e^{\delta14}$
Count, Germany	0.00069***	1,526.12***	0.03***	0***	0***
Count, Czech Republic	0.00086***	5.68 ***	0.08***	0.06***	0.03***
Capacity, Germany	0.00073***	10.23***	0,23**	0.1***	0.05***
Capacity, Czech Republic	0.00067***	0.11***	0.76	1.16	0.78

Note: pv1 as a basis; *** significant at 1% level of significance, ** significant at 5% level of significance, *significant at 10% level of significance; 0 represents a value lower than 0.005

Source: own calculations

As apparent from values reported in table, Germans are much more likely to invest in photovoltaic RES-E that Czechs. At zero NPV, there would be over 1,500 small installations per million of inhabitants in Germany, compared to 6 in the Czech Republic. Conversely, the reaction of Czech investors to change in the NPV of a unit of installed capacity is higher than that of German investors, but this holds only in case of number of installations. For capacity, response by German and Czech investors is roughly the same. For the Czech Republic, both count and installed capacity are skewed towards larger installations relative to Germany. This is most visible for the capacity of large installations: at a given level of NPV, the capacity of large installations will be at 80% of capacity of the small ones in the Czech Republic, while only at 5% in Germany. Overall, Germans are keener to invest into photovoltaic RES-E, as is apparent on following table.

Table 2: Comparison of individual size class response between Germany and Czech Republic

	count e^δ	cap e^δ
pv1	0***	0.01***
pv2	0.01***	0.04***
pv3	0.05***	0.16***
pv4	0.25	0.21

Note: the German case as basis, values of regression coefficents reflect lower appetite of Czech investors for investments into PV RES-E

Source: own calculations

The difference between Germany and the Czech Republic is clearly visible: while the tendency of Czech investors to invest into a RES-E system at low NPV is negligible when compared to their German counterparts, the difference narrows as one moves towards larger installation classes. However, Czech market stays less developed in this respect.

Table 3: Yearly regression of number and capacity of photovoltaic RES-E projects on their NPV, zero values dropped

	Coefficient β	intercept pv1 e^α	intercept difference between pv2 and pv1 $e^{\delta 12}$	intercept difference between pv3 and pv1 $e^{\delta 13}$	intercept difference between pv4 and pv1 $e^{\delta 14}$
Count, Germany	0.00064***	1,336.54***	0.03***	0***	0***
Count, Czech Republic	0.00093***	14.63***	0.05***	0.08***	0.05***
Capacity, Germany	0.00070***	9.48***	0.23***	0.11***	0.16***
Capacity, Czech Republic	0.00092***	0.09***	0.4	5.39*	20.46***

Source: own calculations

Dropping zero values rather than replacing them paints fairly different picture. While this approach disregards the decision by certain investors not to invest in photovoltaic RES-E, including those cases poses a serious threat to the validity of outputs of the model. Based on tests performed, neither normality nor homoskedascity or inclusion of all relevant explanatory variables can be assumed. When clear of zero values, the model performs notably better, as heteroskedascity is rejected in all the cases. The non-normality of data is not rejected in case of installation count in Germany, and in both Germany and Czech Republic the RESET test hypothesis is rejected. The non-normality would become a serious threat only in case hypotheses were tested, the RESET hypothesis rejection is explained in following paragraphs.

Using the model that drops zero values the Czech market is even more responsive to change in return, both in terms of installed capacity and in terms of number of installations. While for both Germany and the Czech Republic most of the coefficients tend to stay close to values predicted by the previous version of the model, a substantial shift is apparent in case of large sources in Czech Republic. While the response to a given NPV in terms of number of installations is similar to previous case, the capacity coefficients grew in case of pv3 (sources from 100kWp to 1MWp) and pv4 (sources over 1MWp and brownfield). While the number of pv4 installations at given NPV will be around 5% of the number of pv1 installations, the sum of capacity of pv4 installations will be over 20 times higher than that of pv1 installations. That said, this alone does not explain the spur of photovoltaic market that both the countries went through.

Figure 9: Yearly installed capacity of different size classes versus returns, Germany
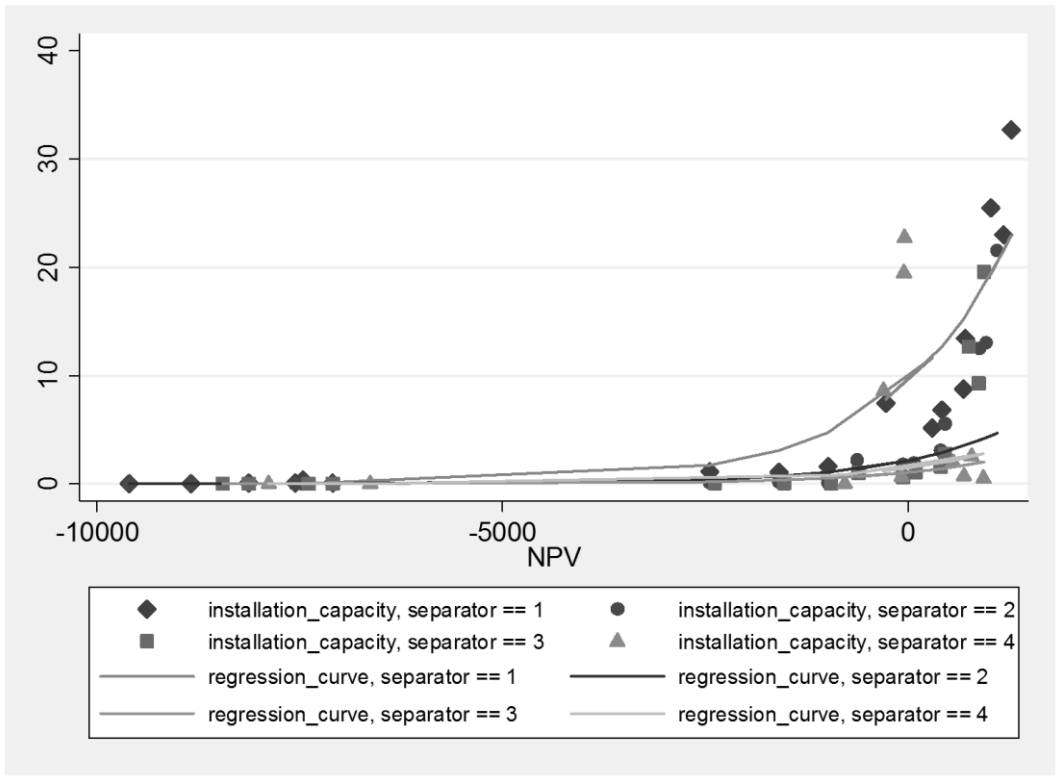
Source: own calculations

On the above figure it is apparent that the German market went through two phases, at first the response of investors was only modest, but recently it picked up to a great extent, with a much stronger response to return on an installation. While a drop in prices was a leading cause of this spur, it alone cannot fully explain it, as its impact on NPV is internalized in the independent variable. It is likely that the market became overcrowded after hitting a trigger point; when a few investors invested into RES-E and began to realize high level of return, they brought the attention of others to it as well.

Figure 10: Yearly installed capacity of different size classes versus returns, Czech Republic
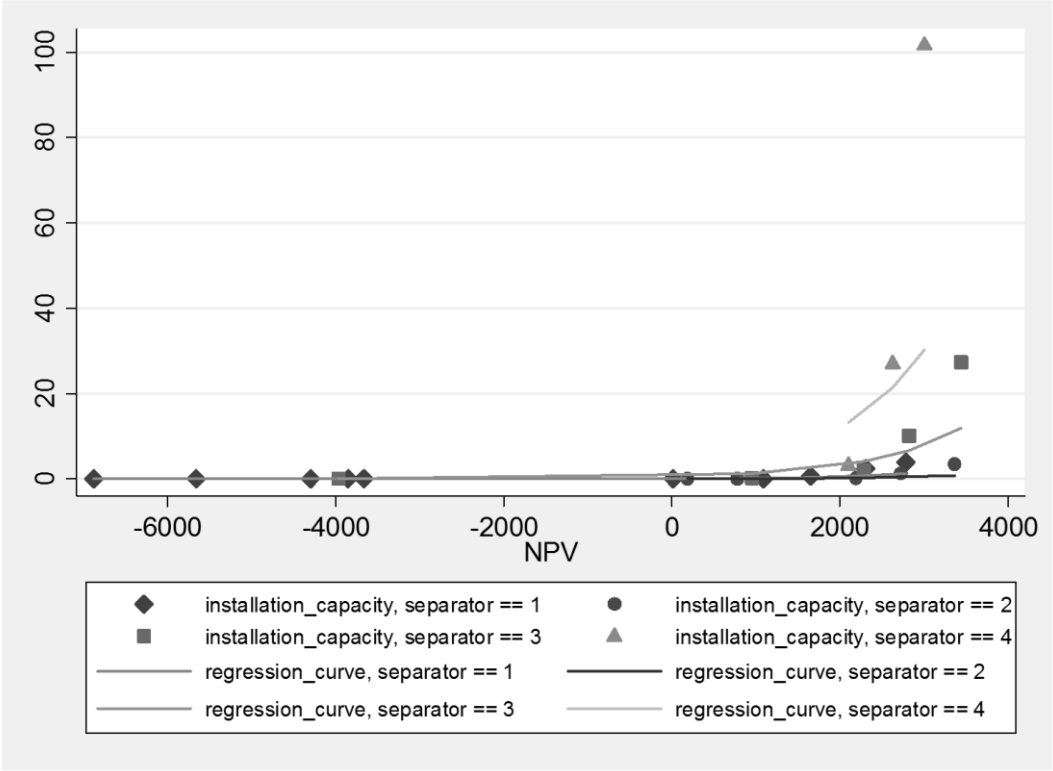
Source: own calculations

In case of the Czech Republic the market spur is even more apparent. While the development of small and medium-small installations is sufficiently described by the regression curves, both the large (above 100kWp) and brownfield (above 1MWp) sources show values above the regression curve in most of their realizations.

While under different circumstances this situation would be resolvable by allowing individual regression curves to have different coefficient beta, this is not possible, as in certain cases, these would be curves based on three or four data points. In next two models the situation is therefore tackled by analyzing monthly data in order to account for diffusion and for the time volatility of differences among regression curves.

4.3 Model 2 – Photovoltaic installations, monthly regression, diffusion

In this model the diffusion of photovoltaic RES-E is analyzed on the monthly data of each of the four size categories. A separate regression is performed on each of the four categories, periods are differentiated by a category variable.

Table 4: Monthly regression of number and capacity of photovoltaic RES-E projects on their NPV, diffusion, Germany

COUNT	Coefficient β	intercept e^{α}	2008 H2	2009 H1	2009 H2
pv1 (up to 30kWp)	0.013***	3.67**	0.14***	0.02***	0.01***
pv2 (up to 100kWp)	0.014***	4.49***	0.06***	0.01***	0***
pv3 (up to 1MWp)	0.012***	0.52	0.09***	0.04***	0.01***
pv4 (over 1MWp)	0.007***	0.01***	1.27	1,748.84***	432.01***
		2010 H1	2010 H2	2011 H1	2011 H2
		0***	0.01***	0.05***	0.04***
		0***	0***	0.01***	0.01***
		0***	0.04***	0.1**	0.07**
		80.86***	579.2***	231.81***	182.1***

CAPACITY	Coefficient β	intercept e^{α}	2008 H2	2009 H1	2009 H2
pv1 (up to 30kWp)	0.014***	0.03***	0.12***	0.01***	0***
pv2 (up to 100kWp)	0.014***	0.19 ***	0.06***	0.01***	0***
pv3 (up to 1MWp)	0.012***	0.1***	0.1***	0.04***	0.02***
pv4 (over 1MWp)	0.007***	0.01***	1.82	2,664.27***	711.39***
		2010 H1	2010 H2	2011 H1	2011 H2
		0***	0.01***	0.05***	0.03***
		0***	0***	0.01***	0.01***
		0.01***	0.04***	0.12**	0.09**
		126.25***	1,326***	425.17***	460.95***

Note: 2008 H1 as a basis

Source: own calculations

In case of Germany the period of 2008 to 2011 was divided into half-year periods due to a double peak occurring during each year, as described in the chapter on methodology. Please note that quality of analysis might be invalidated to some extent by rather low R-squared of regressions, ranging from 0.65 to 0.55 for counts and 0.66 to 0.58 for capacities. Furthermore, non-normality is not rejected in the cases of count of pv3 in Germany and pv4 in Czech Republic; RESET hypothesis is rejected for both count and capacity of pv3 and pv4 in Germany and for the count of pv1 in Czech Republic. The worst offender is the capacity of pv4 in the Czech Republic, in this case heteroskedascity is not rejected. This is caused by a rather flat relationship between NPV and activity of investors into brownfield installations in 2008 and could be attributed to the early stage of the market. While these issues invalidate the regression outputs to some extent, from visual analysis of plots it is nevertheless apparent that the general conclusions continue to be valid.

The response of an investor is lower the larger the installation size for both number and capacity of photovoltaic RES-E installations. In all cases the investors are more sensitive within a year than among the years, with coefficient beta higher by one order. Interestingly the diffusion of RES-E among different classes of investors is exactly opposite to what would be normally expected: in both number of installations and their capacity the relationship with given NPV initially weakens with time and rebounds in later periods only to certain extent. However, this does not hold for large installations. Converse to other size classes, beginning in 2009 the pv4 investors are willing to invest more in terms of both number of installations. This is apparent in the following figures.

Figure 11: Capacity diffusion in Germany, small (pv1) sources (above) and large (pv4) sources (below)
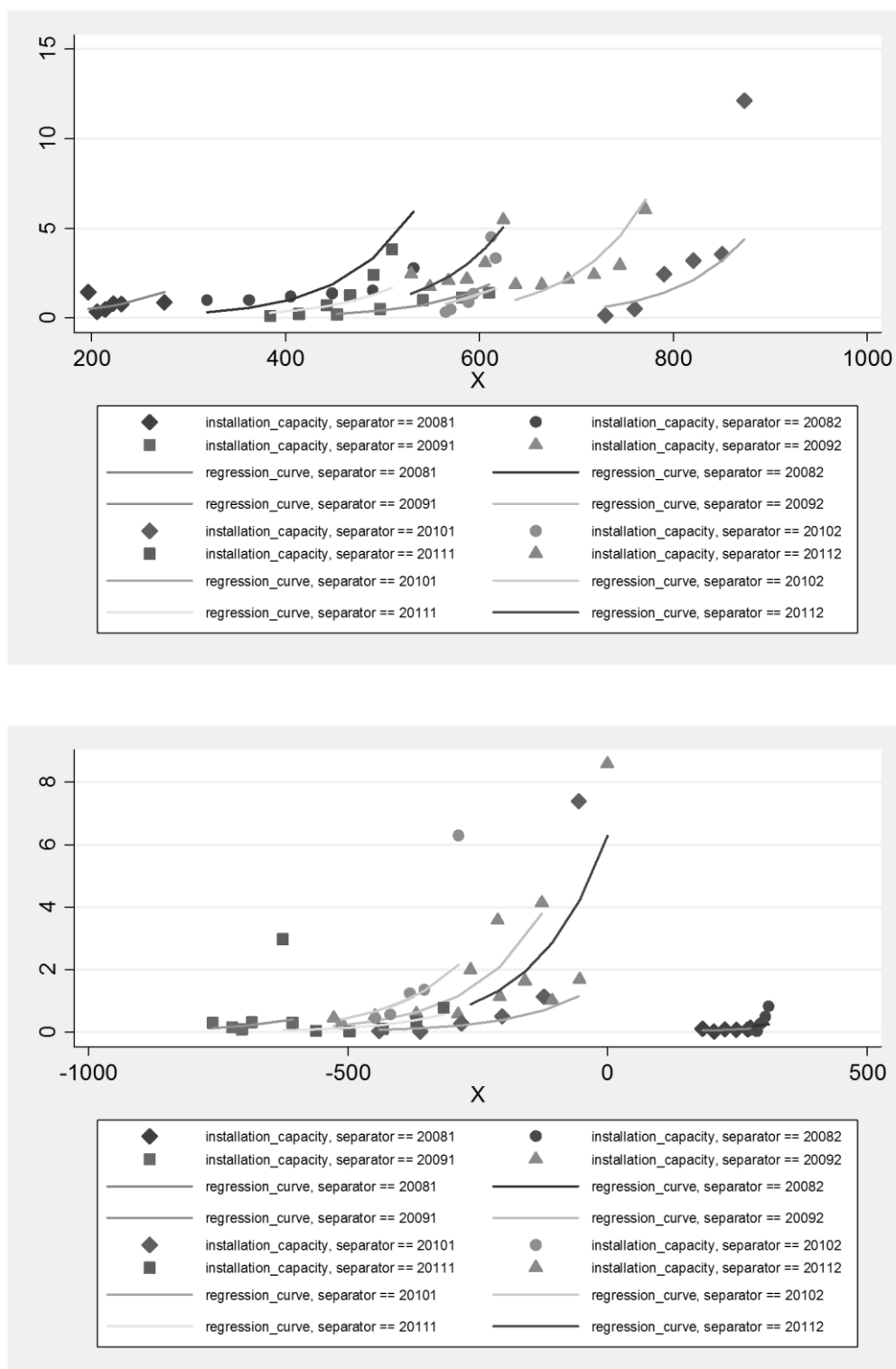
Source: own calculations

For small sources the diffusion is negative from the beginning of the period to the first half of 2010, only then it becomes positive. On the other hand, the relation

between NPV and capacity of large sources strongly expands in 2009, peaks again in the second half of 2010 and stays at levels well above those of the beginning of the period by its end.

Table 5: Monthly regression of number and capacity of photovoltaic RES-E projects on their NPV, diffusion, Czech Republic

COUNT	Coefficient β	intercept e^{α}	2009	2010
pv1 (up to 30kWp)	0.008***	0***	0.02***	0***
pv2 (up to 100kWp)	0.012***	0***	0***	0***
pv3 (up to 1MWp)	0.010***	0***	0.01***	0***
pv4 (over 1MWp)	0.018***	0***	0.17***	0***

CAPACITY	Coefficient β	intercept e^{α}	2009	2010
pv1 (up to 30kWp)	0.009***	0***	0.01***	0***
pv2 (up to 100kWp)	0.013***	0***	0***	0***
pv3 (up to 1MWp)	0.012***	0***	0***	0***
pv4 (over 1MWp)	0.019***	0***	0.16***	0***

Note: year 2008 as a basis

Source: own calculations

The Czech data do not exhibit the two yearly peaks as the German data does, the period of 2008-2010 is therefore divided by years. Furthermore, the R-squared is in this case sufficiently high (above 70%) in all the cases. There is no evidence of any stronger diffusion in any of the observed years. However, contrary to the German case, coefficient beta of large installations in the Czech Republic is substantially higher both in terms of count and capacity.

4.4 Model 3 – Photovoltaic installations, monthly regression, difference among size classes

The monthly data were approached slightly differently in this case. Instead of analyzing change in relationship between NPV and installed capacity or count of istallations in given size class with time, this time around differences among size classes were analyzed in respective years.

The year 2010 was split into two half-year periods due to a change in the levels of tariff for all the size categories that destabilized the market to certain extent. While the fit of the count regression is sufficient in all the cases, the fit of the capacity regressions is worse with an R-squared ranging from 0.53 to 0.81. As in case of previous model, some of regression assumptions are breached. Non-normality is not rejected for both count and capacity in Germany in 2008 and for capacity also in 2009, in the second half of 2010 and in 2011. In case of the Czech Republic, normality is breached for count in the year 2009 and for capacity in 2010. The hypothesis of RESET test is rejected for capacity in Germany in 2010, for both count and capacity in Germany in 2011 and in the Czech Republic in 2009 and 2010. Heteroskedascity is not rejected for capacity in Germany in 2008 and 2011. In both the cases the probable reason for heteroskedascity is the assumption of common beta. From visual analysis of actual and fitted values it seems that in case of pv4 the beta given by the common beta regression is lower than what it would be, should the common beta assumption be scrapped. As is the case with previous model, while these issues invalidate the regression outputs to some extent, the general conclusions made continue to be valid.

Table 6: Monthly regression of number and capacity of photovoltaic RES-E projects on their NPV, difference among size classes, Germany

| COUNT	Coefficient β	intercept e^{α}	intercept difference between pv2 and pv1 $e^{\delta 12}$	intercept difference between pv3 and pv1 $e^{\delta 13}$	intercept difference between pv4 and pv1 $e^{\delta 14}$
2006	0.001***	49.88**	0.08***	0.01***	0***
2007	0.005***	17.97***	0.22***	0.02***	0***
2008	0.004***	29.86***	0.17***	0.02***	0***
2009	0.005***	5.81***	0.23***	0.03***	0.4
2010 H1	0.012***	0.02*	0.52	0.2	377.58
2010 H2	0.022***	0***	0.97	1.59	5,498,467.64***
2011	0.008***	2.12	0.21***	0.08***	1.06

CAPACITY	Coefficient β	intercept e^{α}	intercept difference between pv2 and pv1 $e^{\delta 12}$	intercept difference between pv3 and pv1 $e^{\delta 13}$	intercept difference between pv4 and pv1 $e^{\delta 14}$
2006	0.001***	0.46***	0.36***	0.16***	0.11***
2007	0.006***	0.16***	1.04	0.44	0.28***
2008	0.004***	0.28***	0.75	0.33***	0.17***
2009	0.005***	0.05***	0.96	1.46	126.36***
2010 H1	0.020***	0***	6.13***	29.86***	185,864,784***
2010 H2	0.023***	0***	4.98**	42.55***	5,720,488,267***
2011	0.008***	0.02***	0.99	1.8	376.51***

Note: pv1 size class as a basis

Source: own calculations

The main finding of the regression of German data is the gradual shift in time from the small generators towards the large ones as the class eager to install photovoltaic RES-E. While the reaction of large installations to NPV dropped back to that of their small counterparts in terms of count after the regulator intervention of 2010, the 2011 pv4 market continued to have a much stronger reaction to NPV than markets of smaller size classes. Moreover, investors in all the categories became more sensitive to changes in return as the market matured.

Figure 12: Difference in relationship between NPV and installed capacity of different size classes in 2007 (above) and second half of 2010 (below), Germany
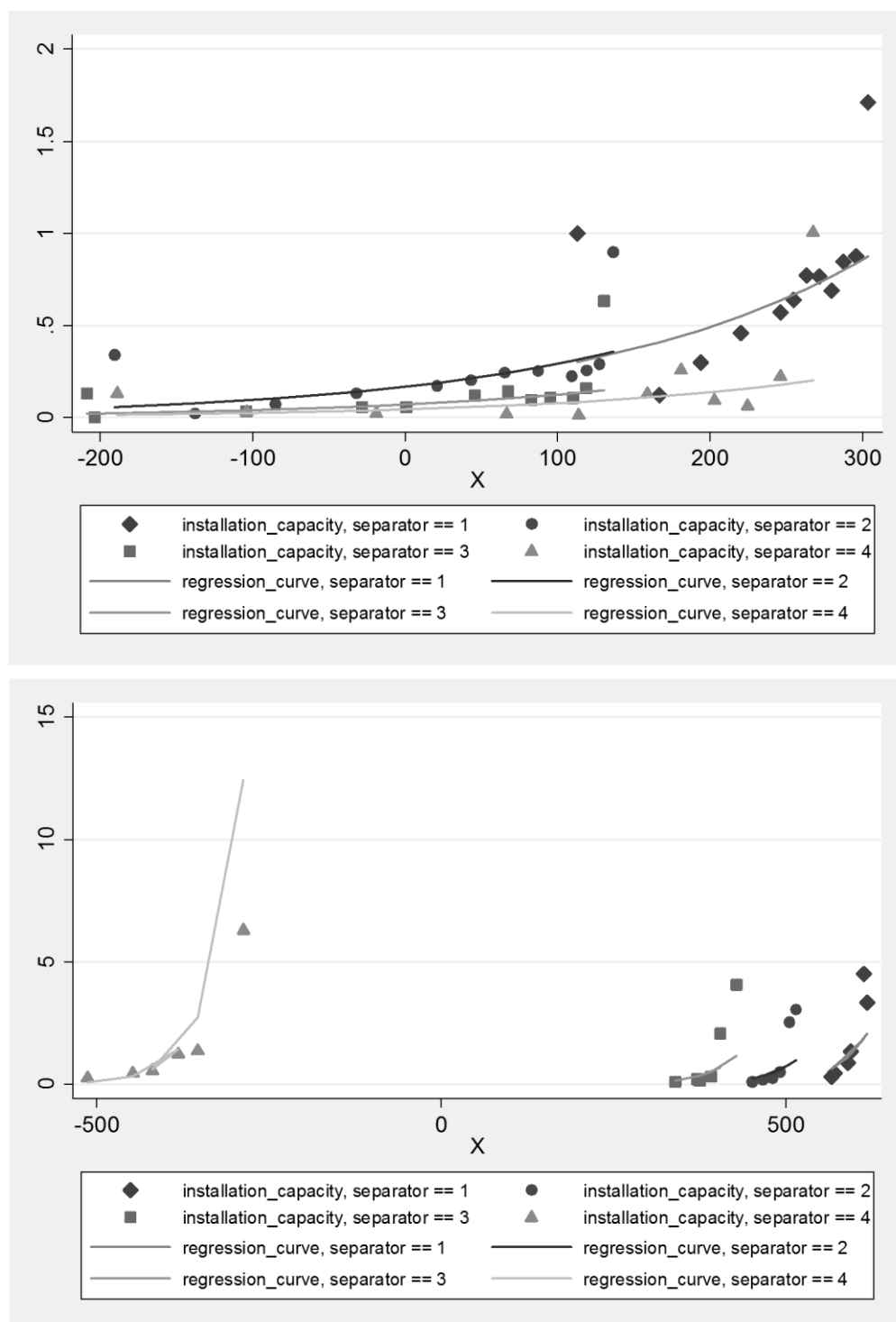
Source: own calculations

As apparent in the figure above, with maturing of the whole PV market the responsiveness of investors in different size classes turned around completely. While in 2007 investors in small and medium-small installations would install the largest capacity at a given return, in second half of 2010 the large investors would install large capacities at levels of return at which no other class would. This shift began in 2009 in terms of capacity and in 2010 in terms of the number of installations.

Table 7: Monthly regression of number and capacity of photovoltaic RES-E projects on their NPV, difference among size classes, Czech Republic

COUNT	Coefficient β	intercept α, (e^{α})	intercept difference between pv2 and pv1 δ_{12}, $(e^{\delta 12})$	intercept difference between pv3 and pv1 δ_{13}, $(e\delta 13)$	intercept difference between pv4 and pv1 δ_{14}, $(e^{\delta 14})$
2008	0.007***	0***	0.06***	0.03***	0.04***
2009	0.013***	0***	0.07***	0.03***	13.47***
2010	0.011***	0***	0.17***	0.09***	0.14***

CAPACITY	Coefficient β	intercept α, (e^{α})	intercept difference between pv2 and pv1 δ_{12}, $(e^{\delta 12})$	intercept difference between pv3 and pv1 δ_{13}, $(e^{\delta 13})$	intercept difference between pv4 and pv1 δ_{14}, $(e^{\delta 14})$
2008	0.009***	0***	0.49*	1.58	7.67***
2009	0.014***	0***	0.55***	1.69**	8,155.04***
2010	0.013***	0***	1.04	3.53***	47.38***

Note: pv1 size class as a basis

Source: own calculations

Regarding the Czech case, quite interestingly, after an expansion in 2009 the tendency to invest in large installations dropped in 2010 in terms of both capacity and count. However, while for count the small investors became the most eager to react again, in the case of count the market stayed skewed towards the large investors. Moreover, the results in both 2009 and 2010 underestimate the relationship between NPV and installed capacity or count in case of large investors due to the common

coefficient beta assumption. Indeed, while the common beta equals to 0.013 in this case, model 2 reports common beta coefficent among pv4 sources in the Czech Republic and across years of 0.019. This is one of the reasons why in some cases the residuals tend to be heteroskedastic. The underestimation is clearly visible on the next figure.

Figure 13: Difference in relationship between NPV and installed capacity of different size classes in 2009, Czech Republic
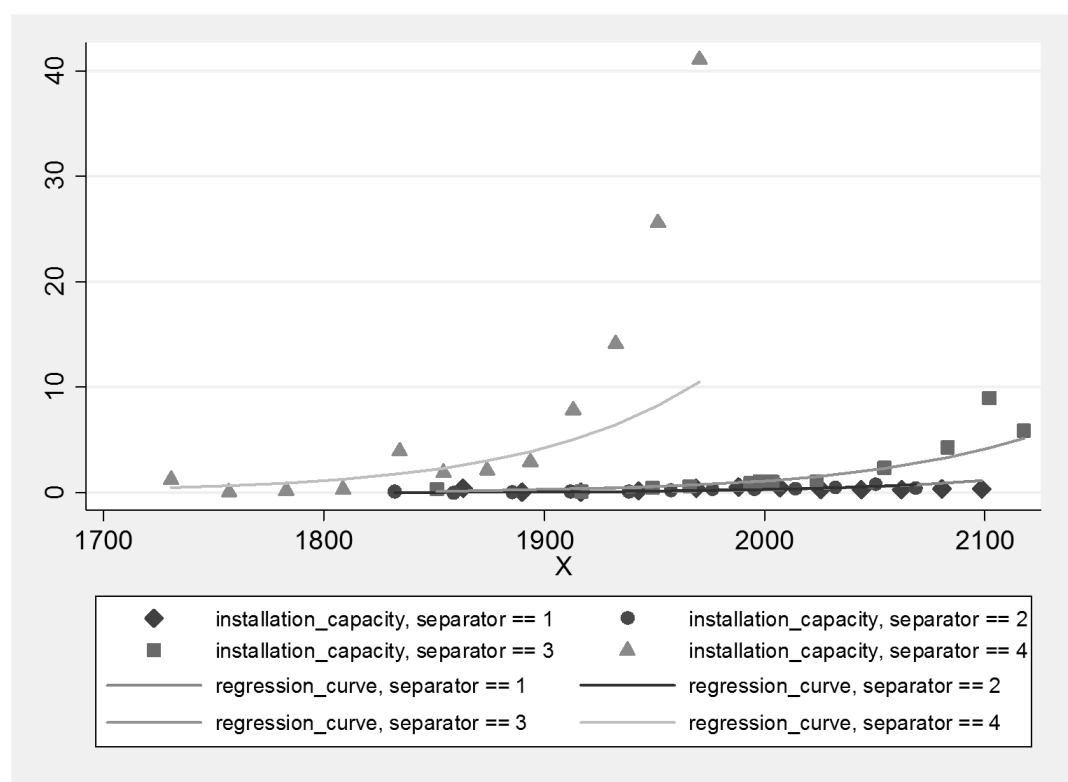
Source: own calculations

5 Forecasting

5.1 Setup of the forecasting model

The fourth model was devised in order to compare predictions of Czech market development under different assumptions. Three scenarios were examined: a Baseline scenario that uses historical data for a period until September 2012 and a forecast for the period until 2020; a Passive regulator scenario that shows how the market could develop under the assumption that Czech regulators simply implement German tariff set-up from 2005 onward without any modification; and an Active regulator scenario that implements the German tariff scheme in 2005 but allows for Czech regulators to adjust tariff rates in case of adverse market development. The forecast of relationship between NPV and installed capacity or count is based on the variation of the first model that drops zero values, as it is better at describing reaction of market once after it has been established.

A parameter that combines diffusion and variable difference between size classes is assumed for each year. For the years 2006 to 2010 this parameter is devised by shifting the regression curve for a given class of installations through the actual realized capacity or a count of installations in given year. The diffusion parameter is given as follows.

$$\rho = lnY - \alpha - \beta.NPV \qquad (10)$$

Where:
- Y is either capacity in MWp installed per million of inhabitants or number of installations per million of inhabitants in given class and year in Czech Republic;
- NPV is the net present value of given installation class in given year in Czech Republic; and
- alpha and beta are based on the version of the first model with dropped zero values.

To forecast the relationship between NPV and installed capacity or count of PV installations from 2011 onward, the approach of Wand & Leuthold (2011) was followed with some adjustments. In their paper the diffusion rate is devised by shifting the regression curve through the last actual realization, the count of

installations and NPV per watt peak of an installation as of year 2007 (the last year of their data set), and dividing the difference by number of years in the period they observed. This approach, adjusted for our case, is captured by the following equation.

$$\gamma = \frac{e^{\alpha + \rho_{2010}}}{e^{\alpha}(2010 - 2006 + 1)} \tag{11}$$

The capacity resulting from diffusion is then devised by multiplying this rate by installed quantity in past year and a position on a sigmoid curve that has the maximum at the maximal annual market potential for residential PV systems. The diffusion parameter used in Wand & Leuthold (2011) is therefore dependent not only on time passed and on last year's installed count, but also on maximal count that could be installed in given year. This approach is not suitable for our case, because to be properly used, the annual market potential for each of the different classes would have to be used. Such parameter is usually obtained using GIS techniques (Bergamasco and Asinari 2011 for case of Piedmont, Italy; Carrión et al. 2008 for case of Andalusia, Spain; and many others) and was not yet estimated for the Czech roof-top space. Most likely it could not be estimated for the ground-mounted systems, as availability of brownfield space is not a relevant estimate of space available for such projects. For that reason, the market potential is assumed to be unlimited and therefore drops out, as described in following two equations.

$$diff_t = \gamma . Y_{t-1} . (1 - \frac{q_{t-1}}{q^{max}}) \tag{12}$$

for $q^{max} -> \infty$:
$$diff_t = \gamma . Y_{t-1} \tag{13}$$

Where:
- q^{max} is the maximum market size for a given size class.

In the baseline scenario the diffusion parameter was used only for the last quarter of 2012 and was set to zero from 2013 on, as the support scheme for RES-E was assumed to be abolished, cancelling the diffusion. For the other two cases, the parameter was used for the whole period of 2013 to 2020.

5.2 Results of the forecasting model

Under the baseline scenario the market is overcrowded by the brownfield installations. Pv3 and pv4 installations alone suffice to exceed the target set by Czech NREAP of 1695MWp of installed capacity. The role of smaller sources is on the

other hand rather marginal. Out of over 2GWp of installed photovoltaic RES-E the installed capacity of sources under 100kWp accounts only for 158MWp.

Figure 14: Total installed capacity of photovoltaic RES-E in Czech Republic, baseline scenario, MWp
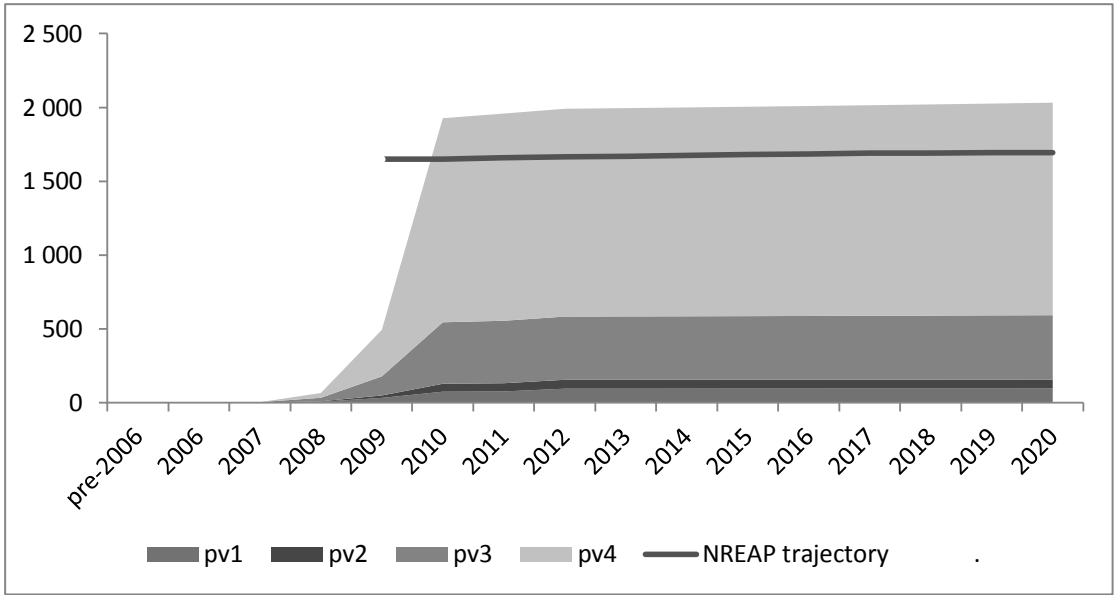
Source: own calculations

Figure 15: Total cost of photovoltaic RES-E in Czech Republic, baseline scenario, CZK bln.
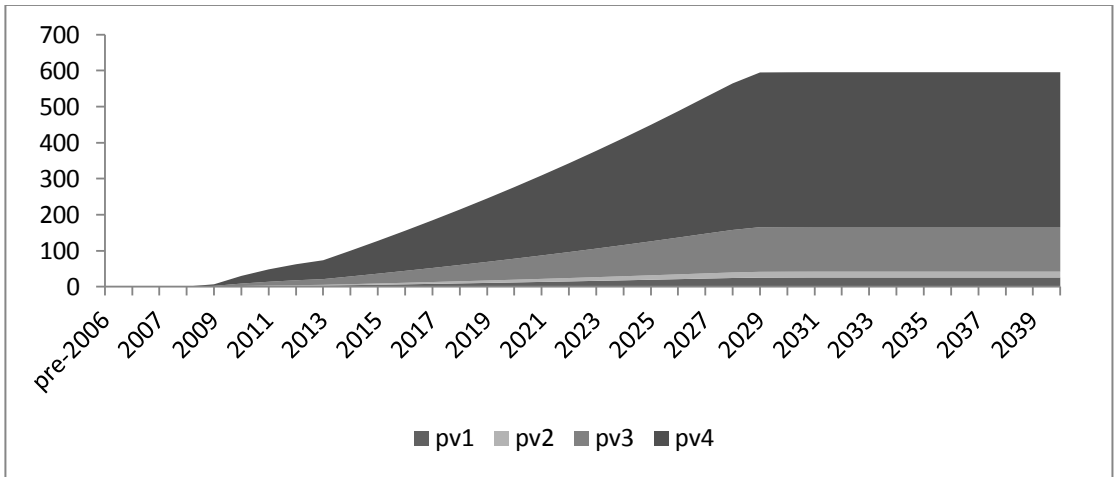
Source: own calculations

The total cost of the support scheme amounts to CZK 596 billion. Out of the total 430 billion will be paid out the largest installations over one megawatt peak, while another 124 billion will go to installations with a 100kWp to 1MWp capacity. These two size categories will therefore receive almost 93% of the overall funding.

Under the passive regulator scenario, the Czech regulator is expected to adopt German tariff levels without any adjustment. Since the German response to the spur of pv4 market was swifter than the Czech one, it leads one to believe that such approach would yield sufficient capacity to fulfill goals set in NREAP at lower costs. The German tariffs are expected to decline by 5% a year beginning in 2013.

Figure 16: Total installed capacity of photovoltaic RES-E in Czech Republic, passive regulator scenario, MWp
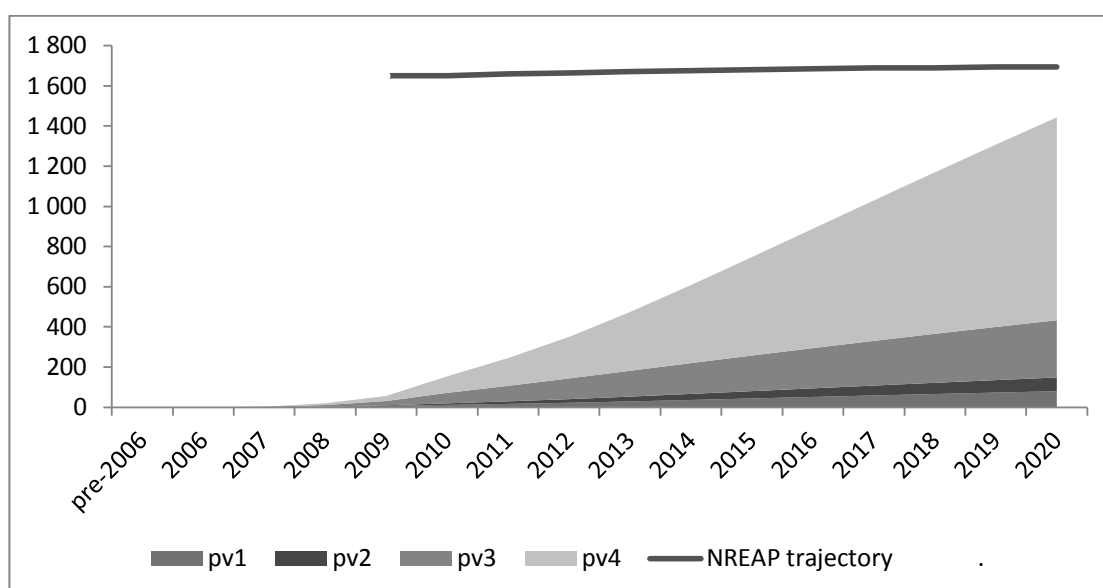
Source: own calculations

The installed capacity under this scenario falls short of fulfilling the capacity goal set for 2020 in Czech NREAP by 250MWp. This is caused by generally lower tendency of Czech investors to invest into photovoltaic RES-E, as shown in the first model. The market is slightly less skewed towards large and brownfield installation class, however, they continue to have a large share of the market at 90% of total installed capacity.

Figure 17: Total cost of photovoltaic RES-E in Czech Republic, passive regulator scenario, CZK bln.
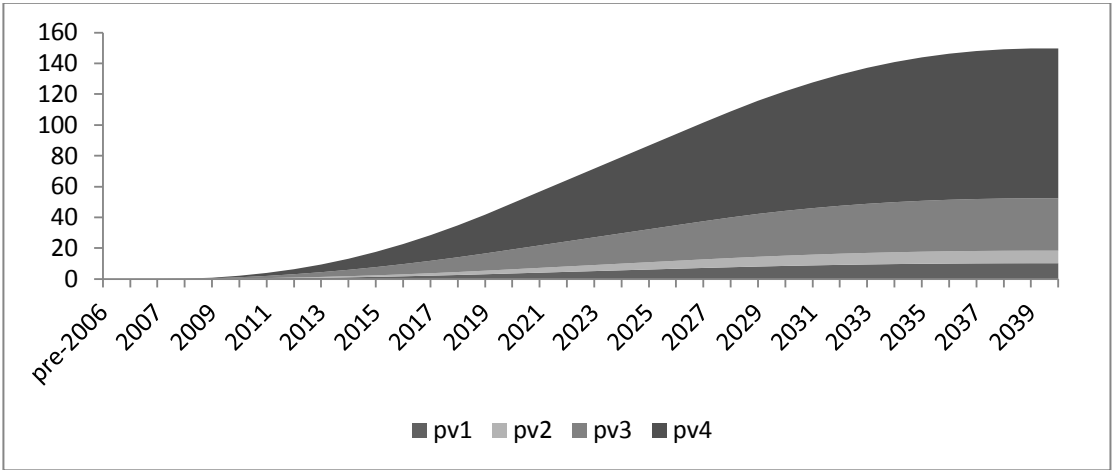
Source: own calculations

While the costs linked to the support scheme continue to be strongly aligned towards the large and especially towards brownfield installations under this scenario, the total sum dropped from almost CZK 600 billion to CZK 150 billion. This is due to more even distribution of capacity installed throughout the duration of the scheme.

Under the active regulator scenario Czech regulator implements German tariff rates in year 2006 only, after that the rates decline by 5% a year as originally assumed. In case either one of the two largest size categories exhibits faster than expected growth in a year, the regulator reduces rate of tariff paid to that size class in the following year so that NPV in the following year is equal to NPV of the previous year. By iterating over the years this approach resulted in regulator intervention from 2015 onward for the pv3 category and from 2010 onward for the pv4 category. The brownfield installation class would cease to be supported in the year 2015.

Figure 18: Total installed capacity of photovoltaic RES-E in Czech Republic, active regulator scenario, MWp
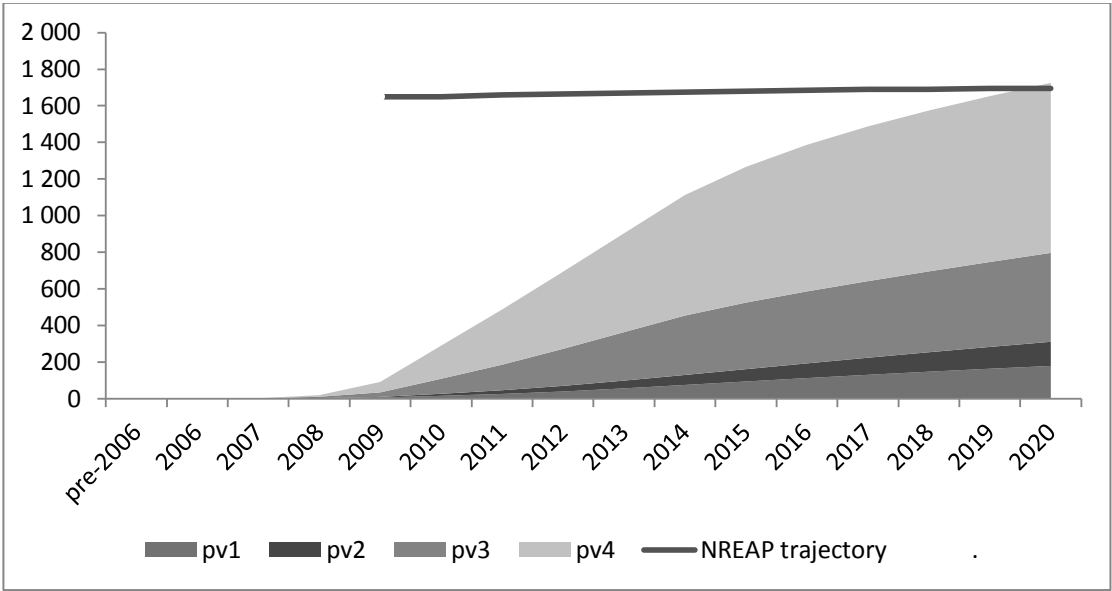
Source: own calculations

Under this scenario the total market capacity in 2020 would rise above the NREAP goal by 30MWp. While not completely even, the division of capacity among classes would be less skewed towards the large and brownfield sources.

Figure 19: Total cost of photovoltaic RES-E in Czech Republic, active regulator scenario, CZK bln.
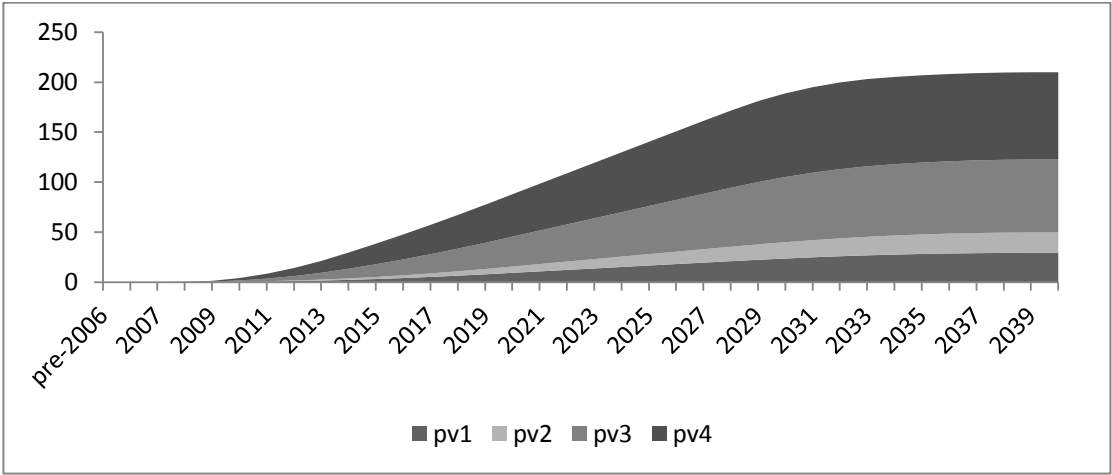
Source: own calculations

Under this scenario the two largest categories of investors would capture around 76% of total tariff revenue that amounts to CZK 210 billion. An active

regulator could adjust the rates paid to installations to a larger extent, which could shift the market composition towards smaller sources even more, however, this would lead to higher overall costs.

6   Discussion

The results of the analysis of the wind RES-E do not indicate any relationship between NPV and wind installations that could be surveyed by an econometric model, neither by count nor by capacity. This is attributable to the investors being in a more complicated position compared to photovoltaic RES-E. This has to do with his or hers ability to correctly estimate costs and revenues of a wind installation at the moment of decision whether to invest or not. In a paper on offshore wind, van der Zwaan et al. (2012) analyzed specific costs of wind energy with the conclusion that the cost-decreasing effects of learning and scale were outweighed by spurs in prices of commodities used in production of wind turbines and other parts of an installation. For example, the price of copper rose from around 2,000€ (2010) per ton in year 2000 to almost 6,000€ in 2007, just to drop below 4,000€ in 2010. Similarly, the price of steel rose from around 300€ per ton through 1,000€ in 2008 and dropped again to 600€ in 2010. While the price volatility of commodities has a slightly lesser impact on onshore installations, analyzed in this paper, due to less complicated structure of such installations (no need for an artificially constructed platform, shorter distance to grid), prices of these were nevertheless strongly impacted. Along with unstable fixed costs, wind RES-E development is further complicated by administrative requirements and rules, which is especially influential in the UK, as described by Woodman and Mitchell (2011).

While there is no analytical approach that could describe the relationship between RES-E investments and their return, the difference in ability of different types of schemes to attract investor attention is clearly visible. Under the German support scheme, investors are eager to invest into an installation even at low IRR levels around zero, however, in the other countries this eagerness is lacking. In the Czech Republic this might be explained by the wind energy market being not fully evolved from its nursing to its bridging phase. This is particularly due to a lack of faith by investors in the stability and sustainability of the market and crowding-out of the wind RES-E market in favor of photovoltaic RES-E. However, the history of RES-E in the UK is much longer, beginning with NFFO in early 1990's. The most likely explanation of UK investors needing higher return than their German counterparts is therefore a uncertainty on returns linked to the UK system and lack of thereof in Germany, accompanied by high transaction costs linked to ROC trading that prohibit smaller sources to take part.

The analysis performed on photovoltaic RES-E data leads to a number of interesting conclusions. Firstly, Czech investors are generally less eager to invest in photovoltaic RES-E. This is most probably caused by differences in the local specifics of German and Czech markets, however, as Lipp (2007) puts it, while local factors are important, policy design is of higher importance. Furthermore, Masini and Menichetti (2012) suggest that an investor's decision to invest in a RES-E project is motivated not only by return of such investment, but also by a belief by that investor in the technological adequacy and his or hers confidence in policy measures. Both seem to be lacking to some extent in the Czech market, rightfully so in the case of policy measures.

Secondly, the response of an investor to return is much stronger in the course of a year than among years. This could be explained by the investor making the decision to invest in a given year and waiting for the point of highest return in that year.

Thirdly, the behavior of the investors changes in the course of the support scheme, as suggested by the first model. While in the first phase of the market the tendency of investors to invest is more lenient, in the second phase investor perceptivenesss of changes in NPV grows. This is partially explained by the maturing of the market, as described by Bergek and Jacobsson (2010). The shift that occurred in both Germany and Czech Republic sometime around 2008 is, using their vocabulary, a progression of the markets from the nursing to the bridging phases.

The dynamics and alignment of the shift is explained in models 2 and 3 using monthly data. Firstly, while market diffusion of renewable RES-E is often modeled as a steady growth of installed capacity above the level suggested by return (Wand & Leuthold 2011, van Benthem et al. 2007), analysis of diffusion effects shows that this process is not monotonous, the relationship between NPV and investments into PV RES-E across the years weakens at some points and rebounds again at a later point in time. The most plausible explanation is that there is a stock of early adopters who decide to invest at a positive but relatively lower return. However, the stock gets depleted after certain time, and other types of investors begin to enter the market. In other words, the positive diffusion effect begins to occur as more of the regular investors get convinced to invest in a photovoltaic installation.

The shift between phases of the market changes impacts of different types of investors differently. In the first phase the tendency of the investors to invest in brownfield photovoltaic installations is weaker compared to investors in small installations, but after the shift it becomes distinctively stronger. Along with that, the

capacity installed in brownfield installations grows significantly. The decline of fixed costs of photovoltaic installations is internalized in the explanatory variable, the reason for this change must therefore be different. A plausible explanation is that as the market grows, investors in brownfield photovoltaic RES-E begin to perceive investments in it as a more viable investment opportunity. When attracted to a market, a professional investor will be relatively more perceptive to changes in return and is more able to capture revenues from tariffs than a household or other small investor. In this context, a sudden change of the relationship pattern and subsequent rapid growth of large installation is a consequence of the establishment of a more mature market.

The sudden spur in the installation of photovoltaic RES-E stimulated German and Czech regulators to react differently, both in terms of swiftness and magnitude. In Germany the tariff rates were subject to yearly review, rates offered in the following year have to be passed by German parliament. Tariffs offered to large and brownfield installations were decreased by a larger share compared to small source tariffs due to this approach. Furthermore, in 2010 the tariffs were decreased in the middle of the year as a response to the market overheating. Conversely, Czech rates decreased only modestly between 2009 and 2010, which was followed by full stop in 2011.

The last model applies German tariff rates to the Czech market in order to assess improvements in cost of the system and other parameters stemming from such an approach. The outcome of the simple application of German tariffs on Czech market is rather ambiguous. As outlined in the first model, the willingness of Czech investors to partake in photovoltaic RES-E is lower than that of German investors across all the size classes; the application of German tariffs therefore yields a total capacity lower than the NREAP goal for photovoltaic RES-E. On the other hand, a decline in costs of the system as compared to the current situation is much stronger than the decline in capacity, simple adoption of German rates would therefore be beneficial from viewpoint of efficiency. In the next scenario it is shown that if the Czech regulator adopted only the initial setup of the German market and adjusted the rates in case of need, the overall cost of the system would be one third of its current cost and the tariffs revenues would be more evenly distributed across the different categories of investors.

It is important to mention that the costs attributed to the scenarios include only explicit values of the system – the total sum of tariff payments paid out to photovoltaic RES-E generators. However, other costs arise with the growth of

installed capacity, particularly those linked to grid construction and maintenance. While the small rooftop installations burden the grid to lower extent and their production is in some cases used locally, brownfield installations with large capacities are a burden to the grid to larger extent, inducing additional cost of grid operation. Total costs of the systems with inclusion of these costs would therefore be more skewed towards large installations.

7 Conclusion and future research

The goal of this paper was to confirm two propositions on support schemes that aim to promote electricity generation from renewable energy sources: Firstly, that neither support schemes based on a set tariff paid out to RES-E producers nor schemes based on marketable certificates dominate each another in terms of effectiveness, efficiency, equity and research, development and diffusion at the same time. Secondly, that the introduction of common support schemes among two comparable EU member states, Germany and the Czech Republic, would bring about better results than the employment of separate schemes specific for each of the countries. Both propositions were analyzed on theoretical basis as well as on analysis of three countries with different approach towards the RES-E market.

From a viewpoint of effectiveness the set tariff-based scheme design offers better performance than the marketable certificate-based one. In the case of the British RO scheme it has been shown that certificate-based schemes are less likely to attract sufficient level of investment into renewable electricity generation. The reason for this is the uncertainty about returns on capital invested in a project. Volatility in certificate prices generates substantial risk for those who invest in RES-E, those investors then require higher level of returns on their investment in order to decide to invest into an installation. Both the scheme categories suffer from changes in exogenous parameters. Under a tariff-based scheme a swift and abrupt change in a variable such as fixed cost of investment or sudden drop in return to comparable investments leads to overinvestment, even the swiftest reaction from market regulator does not mitigate the whole sum of extra costs. In such cases a system based on certificates regulates itself autonomously to a large extent. However, such auto-regulation might harm the market as well. In instances of overshooting the RES-E target in given year the price of a certificate quickly declines, which discourages future investments. While a tariff-based scheme is threatened by the upside risk, the converse is true for a certificate-based scheme. Finally, both scheme categories create markets that would not exist, should the schemes not be in place. However, the shape of the market differs. While the tariff-based scheme could be built with the

involvement of all the investor classes in RES-E generation in mind, a certificate-based scheme will always be skewed towards large electricity sources and away from micro-generation. Overall a tariff based scheme that is set up optimally will bring about sufficient level of installed capacity and build up a diverse, functioning market in the process, a certificate-based scheme carries a significant risk of not fulfilling the set goals and creating a market skewed towards large installations.

Regarding efficiency the situation is much more ambiguous. A certificate-based scheme will in most cases cost more in terms of per-unit costs due to its relative incapability to spur investor interest and the corresponding need to pay the investors more. However, under a certificate-based scheme, as was introduced in Great Britain, the maximum amount paid to a RES-E producer is capped, and the system is therefore threatened by under-generation rather that overpayment. Conversely, a tariff-based scheme introduced under less than optimal circumstances can generate costs that are overly high. Put together, a tariff-based scheme is therefore more likely to fulfill the efficiency criterion, but only if it is implemented with care.

Regarding the equity criterion, a comparison of costs linked to tariffs and certificate prices revealed that the tariff-based scheme of Germany outperforms the certificate-based one of the UK. While the impact of RES-E support on electricity prices is only modest under certificate-based scheme in the UK, it will outgrow that of its tariff-based scheme-using counterparts when the British NREAP targets are fulfilled.

The overall costs of a support scheme might also differ because of other variables that impact final electricity prices, such as the extent to which the electricity distributors are able to pass the costs linked to RES-E support onto the final consumers. Taking the distribution of tariff revenues into account, schemes skewed towards small RES-E sources are more equal, as they allow households and other small generators to recycle part of the costs connected to RES-E support, should they decide to invest in RES-E.

Finally, regarding R&D and diffusion criterion, the findings of the analysis are rather ambiguous. As discussed, in order to invest in R&D, manufacturing firms

need to take part in the market in which they realize sufficient returns, and such a market is more likely to be delivered by tariff-based schemes. However, this holds true only in the expansionary part of a firm's life, as a mature company is able to generate profits abroad. Another way to tackle this issue is to take the progress ratio approach. The more capacity a given technology a scheme attracts, the more it contributes towards a reduction of its costs. In such a case, feed-in tariff would be considered a better option. Nonetheless, there is no direct link between the type of support scheme used and R&D in renewables.

The diffusion criterion is fulfilled to different extent among the three countries. Regarding RES-E producers diffusion, it is crucial for the employed scheme in given country to attract a diversified portfolio of investors. While this was rather successful in Germany and the UK FIT scheme, the certificate-based scheme in the UK performed rather poorly in this respect, and so did the Czech tariff-based scheme. The diffusion of RES-E among individual investor groups therefore seems to be a matter of the quality of the design of the employed scheme rather than its type.

Based on the findings described above, the first proposition is rejected. While a certificate-based scheme may perform well under theoretical circumstances, the chances of finding such scheme in real world are quite slim. The tariff-based scheme employed in Germany outperformed the certificate-based scheme of the UK in most of the criteria while being on par with in the rest. Indeed, the UK government was able to improve performance of the scheme in certain criteria only by introducing measures that shifted the design of the RO scheme towards its FIT-based counterpart and by employing a FIT-based scheme for small installations. That being said, the poor performance of the Czech tariff-based scheme shows that good management of a scheme is crucial for it to function properly.

The second part of the analysis was aimed at assessing whether tying two countries, Germany and the Czech Republic, together by the same setup of a RES-E scheme would be beneficial. The proposition was examined on case of the Czech regulator adopting the setup of German photovoltaic RES-E support scheme, either without any adjustment or with adjusting the tariff rates offered to different size classes of PV installations. It is important to mention that this part of the analysis is dependent on values of parameters that need not to be entirely exact or are used out

of necessity, such as the common beta coefficient assumption used in all the models or that the total capacity of the Czech photovoltaic market is not capped. However, while the individual outcomes of the analysis might differ to certain extent, the general trends outlined continue to be relevant.

A number of trends of the German and Czech photovoltaic markets emerged from the analysis. Firstly, the photovoltaic markets in both countries went through two phases. In the first one the investors were less eager to invest into new technology, while in the second, a more mature photovoltaic RES-E market was established and the investors became much more responsive to the return on their investments in the market. Difference between the two phases was more significant the larger the size of the considered investment. Secondly, both the German and Czech markets began to overheat just after the beginning of the second period. This holds especially for large installations. On the development of the markets following the surge, there was clearly visible difference between attentive and lenient market regulators. Thirdly, it was shown that Czech and German markets react differently under common conditions – the Czechs are generally less eager to invest into photovoltaic RES-E than the Germans. Finally, the diffusion (in terms of changing reaction of investors to fixed level of return across the years) is not linear and positive as usually assumed, its development follows a path of contraction followed by an expansion related to the progress from first to second phase of the market.

Three scenarios were analyzed in order to review the proposition. The baseline scenario was devised in order to outline the current state of things. Under the scenario, costs of the photovoltaic RES-E in Czech Republic amounts to CZK 600 billion, generating mix are strongly skewed towards the largest installations with capacity over one megawatt peak. Excessive capacity over target set for photovoltaic RES-E amounts to over 300MWp.

Under the passive regulator scenario that assumes Czech regulator implementing German feed-in tariffs without any adjustment the total capacity falls short of the target by 250 megawatt peak. This is due to the lower appetite of Czech investors towards photovoltaic RES-E compared to German investors. The overall cost of the system sums up to approximately CZK 150 billion, mainly due to a more

even distribution of installed capacity over time. The composition of the market remains aligned towards large installations.

Under the active regulator scenario the Czech regulator adjusts the adopted German tariffs. By capping the tariff levels for installations with installed capacity between 100 kilowatt and one megawatt and over one megawatt in 2015 and 2010 respectively and ceasing to support the brownfield installations in 2015, the photovoltaic market arrives to total installed capacity just slightly above the target set in NREAP. While the distribution continues to be skewed towards large installations, it is less so when compared to other scenarios. The sum of the tariffs is roughly at one third of those paid out under the baseline scenario.

Given the results of the analysis described above, the second proposition on suitability of joint RES-E market cannot be rejected, at least not for photovoltaic installations. While a straight adoption of German feed-in tariffs results in the total capacity below the target set in Czech NREAP, the total costs of the support scheme that amount only to quarter of costs of the scheme under current state of things more than compensate for that. Should the Czech regulator be more attentive to the market, the desired installed capacity would be reached at fraction of costs as compared to current situation, with a more even distribution of tariffs in both time and among investor classes.

The key contribution of this thesis is its application of so far rarely used framework that inspects the reaction of investors into photovoltaic RES-E on the basis of return to their investments and its analysis of Czech market. Furthermore, the NPV calculations in this thesis utilize the country- and time-specific discount rate calculated in line with the CAPM methodology, as opposed to the constant discount rate usually employed in research papers. This approach captures the decision-making process of an investor in real world and takes into account varying conditions among different countries and years.

The topic of electricity generation from renewable energy sources is far from exhausted. The analysis provided in this paper could be improved and built upon in several ways. First and foremost, this paper tackled the performance of schemes aimed at building of RES-E markets. However, these markets will be sustainable and

lasting after end of the schemes only if the transport and distribution grids adjust to changing shape of the market. The inclusion of the impact of renewable electricity generation on grids would therefore help a great deal to answer the question of sustainability of the RES-E market.

The scope of work could be expanded by including other RES-E types. However, as seen on the case of wind RES-E analysis included in this paper, this is certainly difficult and would involve both more advanced methods and more detailed data that could only be obtainable by a close analysis of individual installations and interviews with investors.

Finally, while the goals for RES-E inclusion into the energy generation mix are set, it is not always clear what the impacts on various actors in economy will be, as well as on the economy as a whole. A cost-benefit analysis of the support schemes would help us to distinguish between the good ideas that will benefit the households, businesses and electricity producers alike and the bad ideas that only waste resources.

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Appendix A: Selected model inputs and assumptions

	Source	Country	Unit	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Electricity market price	Bloomberg (2012)	Germany	EUR/kWh	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,05	0,03	0,07	0,03	0,04	0,05
Electricity market price	Bloomberg (2012)	CzechRep	CZK/kWh	0,24	0,27	0,32	0,46	0,67	0,74	0,81	0,89	0,89	0,92	1,37	1,45	1,08	1,65	1,03	1,14	1,27
Corporate tax rate	1)	Germany	%	17%	20%	20%	21%	24%	24%	17%	16%	16%	17%	18%	20%	21%	20%	18%	16%	16%
Corporate tax rate	1)	CzechRep	%	41%	39%	39%	35%	35%	31%	31%	31%	31%	28%	26%	24%	24%	21%	20%	19%	19%
Plant life	assumption	both		20	20	20	20	20	20	20	20	20	20	20	25	25	25	25	25	25
Exchange rate	2)		CZK/EUR	34,15	34,70	34,46	35,93	36,05	36,88	35,60	34,07	30,80	31,85	31,89	29,78	28,34	27,77	24,95	26,44	25,28
Specific electricity yield PV, installations at and above 1MWp	JRC (2012) and assumption	Germany	Wh/Wp	790	804	817	831	845	858	872	886	899	913	926	940	954	967	981	994	1 008
Specific electricity yield PV, installations at and above 1MWp	JRC (2012) and assumption	CzechRep	Wh/Wp	784	798	811	825	838	852	865	879	892	906	920	933	947	960	974	987	1 001
Specific electricity yield PV, installations below 1MWp	JRC (2012) and assumption	Germany	Wh/Wp	751	764	777	790	803	816	829	842	855	868	881	894	907	919	932	945	958
Specific electricity yield PV, installations below 1MWp	JRC (2012) and assumption	CzechRep	Wh/Wp	746	759	772	785	797	810	823	836	849	862	875	887	900	913	926	939	952
Installation cost per kWp, 1MWp installations and below	BSW (2012) and assumption	Both	EUR/kWp	8 529	7 845	7 190	6 635	6 322	6 649	6 507	5 710	5 154	5 382	5 710	4 900	4 441	4 262	3 485	2 834	2 312
Installation cost per kWp, 1MWp installations and above	BSW (2012) and assumption	Both	EUR/kWp	7 676	7 061	6 471	5 971	5 690	5 984	5 856	5 139	4 639	4 844	5 139	4 410	3 997	3 836	3 137	2 550	2 081
Population	3)	Germany	million	81,54	81,82	82,01	82,06	82,04	82,16	82,26	82,44	82,54	82,53	82,50	82,44	82,31	82,22	82,00	81,80	81,75
Population	3)	CzechRep	million	10,33	10,32	10,31	10,30	10,29	10,28	10,27	10,21	10,20	10,21	10,22	10,25	10,29	10,38	10,47	10,51	10,49
Feed-in tariff level for given capacity		Germany	EUR/kWh																	
<30kWp BIPV	5)				0,08	0,08	0,08	0,08	0,08	0,51	0,51	0,48	0,46	0,57	0,55	0,52	0,49	0,47	0,43	0,36	0,29
<100kWp BIPV	5)				0,08	0,08	0,08	0,08	0,08	0,51	0,51	0,48	0,46	0,55	0,52	0,49	0,47	0,44	0,41	0,35	0,27
<1000kWp BIPV	5)				0,08	0,08	0,08	0,08	0,08	0,51	0,51	0,48	0,46	0,54	0,51	0,49	0,46	0,44	0,40	0,33	0,26
Over 1000kWp BIPV (and FIPV by assumption)	5)				0,08	0,08	0,08	0,08	0,08	0,51	0,51	0,48	0,46	0,54	0,51	0,49	0,46	0,44	0,33	0,27	0,22
Feed-in tariff level for given capacity		CzechRep	CZK/kWh																	
<30kWp	4)															13,20	13,46	13,46	12,89	12,25	7,50
<100kWp	4)															13,20	13,46	13,46	12,79	12,15	5,90
>100kWp	4)															13,20	13,46	13,46	12,79	12,15	5,50
Tariff growth	assumption	CzechRep	%	3,0%																
Maintenance costs	assumption	both	%	1,8%																
Installation time, under 1MWp capacity	assumption	both	years	0																
Installation time, over 1MWp capacity	assumption	both	years	1																
Tax on revenue (for systems over 30kWp installed in 2009 and 2010, fixed tariff receivers, valid for 2011-13)	4)	CzechRep	%	26%																

Growth after 2011:
- Electricity market price growth taken from Bloomberg (2012)
- Corporate tax rate, plant life, exchange rate, population, maintenace cost and installation time kept at 2011 level
- Specific electricity yield assumed to grow at the level of growth of year 2011

1) http://www.oecd.org/tax/taxpolicyanalysis/oecdtaxdatabase.htm#C_CorporateCaptial, accessed 12 June 2012
2) http://www.ecb.int/stats/exchange/eurofxref/html/index.en.html, accessed 12 June 2012
3) http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database, accessed 12 June 2012
4) ERU Decision papers; http://www.eru.cz/dias-browse_articles.php?parentId=113, accessed 12 June 2012
5) Versions of German EEG and StrEg; http://www.bmu.de/english/renewable_energy/downloads/doc/47883.php, accessed 12 June 2012

Appendix B: Inputs for computation of cost of capital

	Source	Country	Unit	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Risk-free rate	Bloomberg (2012) 1)	Germany	%	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.03
Risk-free rate	Bloomberg (2012) 1)	CzechRep	%	0.12	0.12	0.12	0.12	0.07	0.08	0.06	0.05	0.04	0.05	0.04	0.04	0.04	0.05	0.05	0.04	0.04
Market risk	Ibbotson (2012)	both	%	0.07	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Country risk	Damodaran (2012) and assumption	CzechRep	%	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Unlevered beta	Bloomberg (2012) 2)	both		0.35	0.42	0.34	0.22	0.66	0.60	0.78	0.74	0.61	0.62	0.65	0.91	0.78	0.73	0.77	0.55	0.43
Cost of debt	Bloomberg (2012) 3)	Germany	%	0.04	0.03	0.03	0.04	0.05	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.04	0.03	0.03
Cost of debt	Bloomberg (2012) 3)	CzechRep	%	0.11	0.12	0.16	0.14	0.07	0.07	0.07	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03

Please note that different final values of levered, adjusted beta and total cost of capital were devised based on these numbers for each specific case.

1) Based on 10-year or 5-year government bonds of given country.

2) Based on analysis of traded European RES-E producers .

3) For more information please see the Methodology part of this paper.

Appendix C: Regression outputs

Model 1 – Photovoltaic installations, yearly regression

Table 8: Regression outputs, Germany yearly, including zero values, count (above) and capacity (below)

Source	SS	df	MS		
Model	1151.58177	4	287.895443		
Residual	158.884229	63	2.52197188		
Total	1310.466	67	19.5591941		

Number of obs = 68
F(4, 63) = 114.15
Prob > F = 0.0000
R-squared = 0.8788
Adj R-squared = 0.8711
Root MSE = 1.5881

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0006867	.0000496	13.85	0.000	.0005876	.0007857
separator						
2	-3.531898	.544739	-6.48	0.000	-4.620472	-2.443324
3	-5.978652	.5447306	-10.98	0.000	-7.067209	-4.890095
4	-8.519816	.544712	-15.64	0.000	-9.608336	-7.431295
_cons	7.330484	.410206	17.87	0.000	6.510753	8.150216

Source	SS	df	MS		
Model	625.82548	4	156.45637		
Residual	168.228915	63	2.67030023		
Total	794.054395	67	11.8515581		

Number of obs = 68
F(4, 63) = 58.59
Prob > F = 0.0000
R-squared = 0.7881
Adj R-squared = 0.7747
Root MSE = 1.6341

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.000726	.000051	14.23	0.000	.0006241	.0008279
separator						
2	-1.4666	.5605294	-2.62	0.011	-2.586728	-.346471
3	-2.29949	.5605207	-4.10	0.000	-3.419601	-1.179378
4	-3.014504	.5605017	-5.38	0.000	-4.134577	-1.894431
_cons	2.325576	.4220967	5.51	0.000	1.482083	3.169069

Table 9: Regression outputs, Czech Republic yearly, including zero values, count (above) and capacity (below)

Source	SS	df	MS		
Model	941.794017	4	235.448504		
Residual	231.352142	59	3.92122275		
Total	1173.14616	63	18.6213676		

Number of obs = 64
F(4, 59) = 60.04
Prob > F = 0.0000
R-squared = 0.8028
Adj R-squared = 0.7894
Root MSE = 1.9802

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0008639	.0000589	14.66	0.000	.000746	.0009818
separator						
2	-2.494663	.7001221	-3.56	0.001	-3.895604	-1.093721
3	-2.782509	.7003845	-3.97	0.000	-4.183975	-1.381043
4	-3.6216	.7003745	-5.17	0.000	-5.023047	-2.220154
_cons	1.736702	.5528721	3.14	0.003	.6304074	2.842996

```
      Source |       SS       df       MS              Number of obs =      64
-------------+------------------------------           F(  4,    59) =   33.37
       Model |  502.97594      4  125.743985           Prob > F      =  0.0000
    Residual |  222.321456    59  3.76816028           R-squared     =  0.6935
-------------+------------------------------           Adj R-squared =  0.6727
       Total |  725.297396    63  11.5126571           Root MSE      =  1.9412


           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0006655   .0000578    11.52   0.000     .0005499    .0007811
             |
   separator |
           2 |  -.2777634   .6863217    -0.40   0.687     -1.65109    1.095563
           3 |   .1494283   .6865789     0.22   0.828    -1.224413     1.52327
           4 |  -.2480231   .6865691    -0.36   0.719    -1.621845    1.125799
             |
       _cons |  -2.236943   .5419742    -4.13   0.000    -3.321431   -1.152455
```

Table 10: Regression outputs, Germany yearly, dropped zero values, count (above) and capacity (below)

```
      Source |       SS       df       MS              Number of obs =      60
-------------+------------------------------           F(  4,    55) =  106.70
       Model |  679.00267      4  169.750667           Prob > F      =  0.0000
    Residual |  87.497235     55  1.59085882           R-squared     =  0.8858
-------------+------------------------------           Adj R-squared =  0.8775
       Total |  766.499904    59  12.9915238           Root MSE      =  1.2613


           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0006401   .0000442    14.47   0.000     .0005514    .0007287
             |
   separator |
           2 |  -3.537695   .4326548    -8.18   0.000    -4.404755   -2.670636
           3 |    -5.6328   .4477068   -12.58   0.000    -6.530025   -4.735576
           4 |   -7.48005   .4936892   -15.15   0.000    -8.469425   -6.490675
             |
       _cons |   7.197838   .3308115    21.76   0.000     6.534877    7.860799
```

```
      Source |       SS       df       MS              Number of obs =      60
-------------+------------------------------           F(  4,    55) =   61.04
       Model |  429.125744     4  107.281436           Prob > F      =  0.0000
    Residual |  96.6649918    55   1.7575453           R-squared     =  0.8162
-------------+------------------------------           Adj R-squared =  0.8028
       Total |  525.790736    59  8.91170738           Root MSE      =  1.3257


           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0006991   .0000465    15.04   0.000     .0006059    .0007923
             |
   separator |
           2 |   -1.46995   .4547565    -3.23   0.002    -2.381302   -.5585972
           3 |  -2.188031   .4705775    -4.65   0.000     -3.13109   -1.244973
           4 |  -1.858533   .5189088    -3.58   0.001     -2.89845   -.8186167
             |
       _cons |   2.248926   .3477107     6.47   0.000     1.552098    2.945754
```

Table 11: Regression outputs, Czech Republic yearly, dropped zero values, count (above) and capacity (below)

Source	SS	df	MS
Model	139.586367	4	34.8965917
Residual	27.2771596	18	1.51539775
Total	166.863526	22	7.58470575

Number of obs = 23
F(4, 18) = 23.03
Prob > F = 0.0000
R-squared = 0.8365
Adj R-squared = 0.8002
Root MSE = 1.231

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0009288	.0000976	9.51	0.000	.0007237	.0011339
separator						
2	-2.975725	.7558754	-3.94	0.001	-4.56376	-1.38769
3	-2.485384	.72598	-3.42	0.003	-4.010612	-.9601567
4	-2.933186	.9094343	-3.23	0.005	-4.843837	-1.022536
_cons	2.683243	.4212976	6.37	0.000	1.79813	3.568357

Source	SS	df	MS
Model	268.592308	4	67.148077
Residual	36.518931	18	2.0288295
Total	305.111239	22	13.8686927

Number of obs = 23
F(4, 18) = 33.10
Prob > F = 0.0000
R-squared = 0.8803
Adj R-squared = 0.8537
Root MSE = 1.4244

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0009177	.000113	8.12	0.000	.0006804	.001155
separator						
2	-.9206937	.8746004	-1.05	0.306	-2.758161	.9167736
3	1.683856	.8400094	2.00	0.060	-.0809384	3.44865
4	3.0186	1.052279	2.87	0.010	.8078442	5.229355
_cons	-2.367177	.4874706	-4.86	0.000	-3.391314	-1.343039

Model 2 – Photovoltaic installations, monthly regression, diffusion

Table 12: Regression outputs, Germany monthly - diffusion, PV1, count (above) and capacity (below)

Source	SS	df	MS		Number of obs =	47
					F(8, 38) =	9.01
Model	27.709725	8	3.46371562		Prob > F =	0.0000
Residual	14.6125873	38	.384541772		R-squared =	0.6547
					Adj R-squared =	0.5820
Total	42.3223123	46	.920050267		Root MSE =	.62011

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0130244	.0019728	6.60	0.000	.0090306	.0170182
separator						
20082	-1.983249	.5359569	-3.70	0.001	-3.068237	-.8982605
20091	-4.158908	.7223541	-5.76	0.000	-5.621237	-2.696579
20092	-5.103643	1.013452	-5.04	0.000	-7.15527	-3.052016
20101	-6.812174	1.199268	-5.68	0.000	-9.239966	-4.384383
20102	-4.347927	.8079581	-5.38	0.000	-5.983553	-2.712301
20111	-2.910298	.5736577	-5.07	0.000	-4.071608	-1.748989
20112	-3.338287	.7835304	-4.26	0.000	-4.924461	-1.752112
_cons	1.29999	.5097308	2.55	0.015	.2680934	2.331886

Source	SS	df	MS		Number of obs =	47
					F(8, 38) =	9.24
Model	31.7541101	8	3.96926376		Prob > F =	0.0000
Residual	16.3249027	38	.429602702		R-squared =	0.6605
					Adj R-squared =	0.5890
Total	48.0790127	46	1.04519593		Root MSE =	.65544

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0138945	.0020852	6.66	0.000	.0096732	.0181158
separator						
20082	-2.144959	.5664892	-3.79	0.001	-3.291757	-.9981616
20091	-4.388702	.7635049	-5.75	0.000	-5.934337	-2.843067
20092	-5.36286	1.071187	-5.01	0.000	-7.531363	-3.194356
20101	-7.186151	1.267588	-5.67	0.000	-9.752248	-4.620054
20102	-4.604443	.8539857	-5.39	0.000	-6.333246	-2.875639
20111	-3.100547	.6063377	-5.11	0.000	-4.328013	-1.87308
20112	-3.592627	.8281664	-4.34	0.000	-5.269162	-1.916092
_cons	-3.47073	.538769	-6.44	0.000	-4.56141	-2.380049

Table 13: Regression outputs, Germany monthly - diffusion, PV2, count (above) and capacity (below)

Source	SS	df	MS		
Model	40.7076741	8	5.08845926		
Residual	23.9457805	38	.630152119		
Total	64.6534546	46	1.40550988		

Number of obs = 47
F(8, 38) = 8.07
Prob > F = 0.0000
R-squared = 0.6296
Adj R-squared = 0.5517
Root MSE = .79382

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.013991	.0022825	6.13	0.000	.0093702	.0186118
separator						
20082	-2.771467	.7369842	-3.76	0.001	-4.263414	-1.279521
20091	-5.192347	.9736462	-5.33	0.000	-7.163391	-3.221303
20092	-6.22365	1.362961	-4.57	0.000	-8.98282	-3.46448
20101	-8.099415	1.576818	-5.14	0.000	-11.29152	-4.907314
20102	-5.962904	1.160498	-5.14	0.000	-8.31221	-3.613597
20111	-4.52449	.8906444	-5.08	0.000	-6.327505	-2.721474
20112	-5.159886	1.169007	-4.41	0.000	-7.526418	-2.793355
_cons	1.50087	.3265821	4.60	0.000	.8397395	2.162001

Source	SS	df	MS		
Model	42.80174	8	5.3502175		
Residual	24.885888	38	.654891789		
Total	67.687628	46	1.47147017		

Number of obs = 47
F(8, 38) = 8.17
Prob > F = 0.0000
R-squared = 0.6323
Adj R-squared = 0.5549
Root MSE = .80925

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0142709	.0023269	6.13	0.000	.0095603	.0189815
separator						
20082	-2.824445	.7513119	-3.76	0.001	-4.345397	-1.303494
20091	-5.25799	.9925748	-5.30	0.000	-7.267353	-3.248627
20092	-6.306256	1.389458	-4.54	0.000	-9.119067	-3.493445
20101	-8.189832	1.607473	-5.09	0.000	-11.44399	-4.935674
20102	-5.950132	1.18306	-5.03	0.000	-8.345111	-3.555153
20111	-4.452628	.9079594	-4.90	0.000	-6.290696	-2.61456
20112	-5.13166	1.191734	-4.31	0.000	-7.544199	-2.71912
_cons	-1.66094	.3329312	-4.99	0.000	-2.334924	-.9869558

Table 14: Regression outputs, Germany monthly - diffusion, PV3, count (above) and capacity (below)

Source	SS	df	MS		
Model	44.9121605	8	5.61402007		
Residual	37.1442273	39	.952416085		
Total	82.0563878	47	1.74588059		

Number of obs = 48
F(8, 39) = 5.89
Prob > F = 0.0001
R-squared = 0.5473
Adj R-squared = 0.4545
Root MSE = .97592

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0119705	.0025998	4.60	0.000	.0067119	.0172291
separator						
20082	-2.393862	.8831723	-2.71	0.010	-4.180246	-.6074773
20091	-3.293834	.9462237	-3.48	0.001	-5.207752	-1.379915
20092	-4.336584	1.457946	-2.97	0.005	-7.285559	-1.38761
20101	-5.418865	1.5857	-3.42	0.001	-8.626246	-2.211485
20102	-3.300322	1.138049	-2.90	0.006	-5.602243	-.998402
20111	-2.253853	.8804584	-2.56	0.014	-4.034748	-.4729576
20112	-2.672732	1.201976	-2.22	0.032	-5.103958	-.2415067
_cons	-.6630923	.3985827	-1.66	0.104	-1.469302	.1431172

Source	SS	df	MS		Number of obs =	48
					F(8, 39) =	6.60
Model	50.1938404	8	6.27423005		Prob > F =	0.0000
Residual	37.0527382	39	.950070211		R-squared =	0.5753
					Adj R-squared =	0.4882
Total	87.2465786	47	1.85631018		Root MSE =	.97472

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0120357	.0025966	4.64	0.000	.0067837	.0172878
separator						
20082	-2.314577	.882084	-2.62	0.012	-4.09876	-.5303938
20091	-3.227514	.9450577	-3.42	0.002	-5.139073	-1.315954
20092	-4.184195	1.45615	-2.87	0.007	-7.129536	-1.238855
20101	-5.232189	1.583746	-3.30	0.002	-8.435617	-2.02876
20102	-3.132838	1.136646	-2.76	0.009	-5.431922	-.833754
20111	-2.08719	.8793734	-2.37	0.023	-3.86589	-.3084889
20112	-2.4538	1.200495	-2.04	0.048	-4.88203	-.0255709
_cons	-2.333288	.3980915	-5.86	0.000	-3.138504	-1.528072

Table 15: Regression outputs, Germany monthly - diffusion, PV4, count (above) and capacity (below)

Source	SS	df	MS		Number of obs =	47
					F(8, 38) =	8.20
Model	52.6738022	8	6.58422528		Prob > F =	0.0000
Residual	30.5065598	38	.802804206		R-squared =	0.6332
					Adj R-squared =	0.5560
Total	83.180362	46	1.80826874		Root MSE =	.89599

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0073209	.0014411	5.08	0.000	.0044036	.0102382
separator						
20082	.2375276	.5249184	0.45	0.653	-.825114	1.300169
20091	7.466708	1.446826	5.16	0.000	4.537763	10.39565
20092	6.068453	.9614779	6.31	0.000	4.122043	8.014864
20101	4.392728	.8619798	5.10	0.000	2.647741	6.137715
20102	6.361644	1.05066	6.05	0.000	4.234694	8.488594
20111	5.445914	1.135719	4.80	0.000	3.14677	7.745058
20112	5.204572	.7398889	7.03	0.000	3.706746	6.702399
_cons	-4.724506	.4982196	-9.48	0.000	-5.733099	-3.715913

Source	SS	df	MS		Number of obs =	47
					F(8, 38) =	7.10
Model	72.3535476	8	9.04419345		Prob > F =	0.0000
Residual	48.4073569	38	1.27387781		R-squared =	0.5991
					Adj R-squared =	0.5148
Total	120.760904	46	2.62523705		Root MSE =	1.1287

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0074177	.0018153	4.09	0.000	.0037428	.0110926
separator						
20082	.5997444	.6612274	0.91	0.370	-.7388405	1.938329
20091	7.887687	1.822532	4.33	0.000	4.198163	11.57721
20092	6.567219	1.211151	5.42	0.000	4.115372	9.019067
20101	4.838279	1.085816	4.46	0.000	2.64016	7.036398
20102	7.189579	1.323492	5.43	0.000	4.51031	9.868848
20111	6.052482	1.430639	4.23	0.000	3.156304	8.94866
20112	6.133285	.9320207	6.58	0.000	4.246508	8.020062
_cons	-4.293835	.6275955	-6.84	0.000	-5.564336	-3.023334

Table 16: Regression outputs, Czech Republic monthly - diffusion, PV1, count (above) and capacity (below)

Source	SS	df	MS		
Model	31.6218904	3	10.5406301		
Residual	10.8526813	32	.339146291		
Total	42.4745717	35	1.21355919		

Number of obs = 36
F(3, 32) = 31.08
Prob > F = 0.0000
R-squared = 0.7445
Adj R-squared = 0.7205
Root MSE = .58236

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]
x	.0076952	.0011871	6.48	0.000	.0052772 .0101132
separator					
2009	-4.104256	.8239973	-4.98	0.000	-5.782684 -2.425829
2010	-5.465266	1.12923	-4.84	0.000	-7.765433 -3.165098
_cons	-6.316376	1.270252	-4.97	0.000	-8.903795 -3.728958

Source	SS	df	MS		
Model	49.9719009	3	16.6573003		
Residual	9.5863742	32	.299574194		
Total	59.5582751	35	1.701665		

Number of obs = 36
F(3, 32) = 55.60
Prob > F = 0.0000
R-squared = 0.8390
Adj R-squared = 0.8240
Root MSE = .54733

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]
x	.0092258	.0011157	8.27	0.000	.0069533 .0114984
separator					
2009	-4.873566	.7744341	-6.29	0.000	-6.451037 -3.296096
2010	-6.369647	1.061308	-6.00	0.000	-8.531459 -4.207834
_cons	-13.24272	1.193847	-11.09	0.000	-15.6745 -10.81093

Table 17: Regression outputs, Czech Republic monthly - diffusion, PV2, count (above) and capacity (below)

Source	SS	df	MS		
Model	54.1841301	3	18.0613767		
Residual	8.27671779	27	.306545103		
Total	62.4608479	30	2.08202826		

Number of obs = 31
F(3, 27) = 58.92
Prob > F = 0.0000
R-squared = 0.8675
Adj R-squared = 0.8528
Root MSE = .55367

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]
x	.012421	.0012785	9.72	0.000	.0097977 .0150443
separator					
2009	-6.771479	.7845309	-8.63	0.000	-8.381204 -5.161755
2010	-8.379436	1.108684	-7.56	0.000	-10.65427 -6.104604
_cons	-14.51619	1.44433	-10.05	0.000	-17.47971 -11.55266

Source	SS	df	MS		
Model	57.8826491	3	19.2942164		
Residual	9.02746062	27	.334350393		
Total	66.9101097	30	2.23033699		

Number of obs = 31
F(3, 27) = 57.71
Prob > F = 0.0000
R-squared = 0.8651
Adj R-squared = 0.8501
Root MSE = .57823

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]
x	.0133681	.0013352	10.01	0.000	.0106284 .0161078
separator					
2009	-7.291072	.8193393	-8.90	0.000	-8.972217 -5.609926
2010	-9.196711	1.157875	-7.94	0.000	-11.57247 -6.820949
_cons	-18.60482	1.508413	-12.33	0.000	-21.69983 -15.50981

Table 18: Regression outputs, Czech Republic monthly - diffusion, PV3, count (above) and capacity (below)

Source	SS	df	MS		Number of obs =	35
					F(3, 31) =	39.33
Model	63.0954106	3	21.0318035		Prob > F =	0.0000
Residual	16.5786847	31	.534796281		R-squared =	0.7919
					Adj R-squared =	0.7718
Total	79.6740953	34	2.34335574		Root MSE =	.7313

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0100369	.0014292	7.02	0.000	.007122	.0129518
separator						
2009	-5.188706	.9279729	-5.59	0.000	-7.081319	-3.296092
2010	-6.270853	1.285456	-4.88	0.000	-8.892558	-3.649147
_cons	-12.60379	1.631712	-7.72	0.000	-15.93169	-9.27589

Source	SS	df	MS		Number of obs =	35
					F(3, 31) =	45.20
Model	76.7967955	3	25.5989318		Prob > F =	0.0000
Residual	17.5559992	31	.566322556		R-squared =	0.8139
					Adj R-squared =	0.7959
Total	94.3527947	34	2.7750822		Root MSE =	.75254

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0120182	.0014707	8.17	0.000	.0090187	.0150178
separator						
2009	-6.39515	.9549333	-6.70	0.000	-8.342749	-4.44755
2010	-7.929817	1.322803	-5.99	0.000	-10.62769	-5.231943
_cons	-15.969	1.679118	-9.51	0.000	-19.39358	-12.54442

Table 19: Regression outputs, Czech Republic monthly - diffusion, PV4, count (above) and capacity (below)

Source	SS	df	MS		Number of obs =	26
					F(3, 22) =	29.14
Model	47.5966572	3	15.8655524		Prob > F =	0.0000
Residual	11.9795538	22	.544525172		R-squared =	0.7989
					Adj R-squared =	0.7715
Total	59.576211	25	2.38304844		Root MSE =	.73792

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0175015	.002159	8.11	0.000	.0130241	.021979
separator						
2009	-1.760068	.5230664	-3.36	0.003	-2.844841	-.6752945
2010	-11.46408	1.677985	-6.83	0.000	-14.94401	-7.984151
_cons	-20.96503	2.404252	-8.72	0.000	-25.95114	-15.97891

Source	SS	df	MS		Number of obs =	26
					F(3, 22) =	23.24
Model	57.5639833	3	19.1879944		Prob > F =	0.0000
Residual	18.1616981	22	.82553173		R-squared =	0.7602
					Adj R-squared =	0.7275
Total	75.7256813	25	3.02902725		Root MSE =	.90859

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0192562	.0026583	7.24	0.000	.0137432	.0247692
separator						
2009	-1.83927	.6440428	-2.86	0.009	-3.174933	-.5036068
2010	-12.59074	2.066074	-6.09	0.000	-16.87551	-8.305961
_cons	-22.2869	2.960315	-7.53	0.000	-28.42622	-16.14758

Model 3 – Photovoltaic installations, monthly regression, difference among size classes

Table 20: Regression outputs, Germany monthly – difference among size classes, year 2006, count (above) and capacity (below)

Source	SS	df	MS
Model	380.592118	4	95.1480294
Residual	18.0419259	41	.440046972
Total	398.634043	45	8.8585343

Number of obs = 46
F(4, 41) = 216.22
Prob > F = 0.0000
R-squared = 0.9547
Adj R-squared = 0.9503
Root MSE = .66336

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0011294	.0004557	2.48	0.017	.000209	.0020498
separator						
2	-2.499453	.3059339	-8.17	0.000	-3.117299	-1.881607
3	-4.985856	.3047358	-16.36	0.000	-5.601283	-4.37043
4	-7.498138	.3214882	-23.32	0.000	-8.147397	-6.84888
_cons	3.909664	.1988863	19.66	0.000	3.508005	4.311323

Source	SS	df	MS
Model	47.311218	4	11.8278045
Residual	20.271098	41	.494417025
Total	67.582316	45	1.50182924

Number of obs = 46
F(4, 41) = 23.92
Prob > F = 0.0000
R-squared = 0.7001
Adj R-squared = 0.6708
Root MSE = .70315

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0010621	.0004831	2.20	0.034	.0000865	.0020377
separator						
2	-1.00851	.3242835	-3.11	0.003	-1.663414	-.3536063
3	-1.853976	.3230135	-5.74	0.000	-2.506315	-1.201637
4	-2.248341	.3407707	-6.60	0.000	-2.936542	-1.560141
_cons	-.7705024	.2108152	-3.65	0.001	-1.196252	-.3447524

Table 21: Regression outputs, Germany monthly – difference among size classes, year 2007, count (above) and capacity (below)

Source	SS	df	MS
Model	350.999878	4	87.7499694
Residual	30.7526406	42	.732205729
Total	381.752518	46	8.29896779

Number of obs = 47
F(4, 42) = 119.84
Prob > F = 0.0000
R-squared = 0.9194
Adj R-squared = 0.9118
Root MSE = .85569

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0052183	.0011466	4.55	0.000	.0029044	.0075322
separator						
2	-1.498032	.4304316	-3.48	0.001	-2.366678	-.6293856
3	-3.852857	.4393654	-8.77	0.000	-4.739533	-2.966182
4	-6.500225	.3901164	-16.66	0.000	-7.287512	-5.712939
_cons	2.888453	.3709651	7.79	0.000	2.139815	3.637091

```
      Source |       SS           df       MS            Number of obs =      47
-------------+----------------------------------   F(  4,    42) =   14.21
       Model |  51.5543588         4  12.8885897    Prob > F      = 0.0000
    Residual |  38.1071055        42  .907312035    R-squared     = 0.5750
-------------+----------------------------------   Adj R-squared = 0.5345
       Total |  89.6614643        46  1.94916227    Root MSE      = .95253
```

```
           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0055841   .0012763     4.38   0.000     .0030083    .0081599
             |
   separator |
           2 |   .0412383   .4791439     0.09   0.932    -.9257132    1.00819
           3 |  -.8103008   .4890887    -1.66   0.105    -1.797322   .1767201
           4 |  -1.269652   .4342661    -2.92   0.006    -2.146036   -.3932671
             |
       _cons |  -1.827746   .4129475    -4.43   0.000    -2.661107    -.994384
```

Table 22: Regression outputs, Germany monthly – difference among size classes, year 2008, count (above) and capacity (below)

```
      Source |       SS           df       MS            Number of obs =      48
-------------+----------------------------------   F(  4,    43) =  225.89
       Model |  353.786638         4  88.4466595    Prob > F      = 0.0000
    Residual |  16.8367576        43  .391552502    R-squared     = 0.9546
-------------+----------------------------------   Adj R-squared = 0.9503
       Total |  370.623396        47  7.88560416    Root MSE      = .62574
```

```
           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0035326   .0007633     4.63   0.000     .0019932    .005072
             |
   separator |
           2 |  -1.774034   .2905064    -6.11   0.000    -2.359896   -1.188172
           3 |  -4.115457   .293801    -14.01   0.000    -4.707964   -3.522951
           4 |  -6.995803   .25949     -26.96   0.000    -7.519115   -6.472491
             |
       _cons |   3.396395   .3070838    11.06   0.000     2.777102    4.015689
```

```
      Source |       SS           df       MS            Number of obs =      48
-------------+----------------------------------   F(  4,    43) =   23.94
       Model |  40.4196448         4  10.1049112    Prob > F      = 0.0000
    Residual |  18.1518727        43  .422136574    R-squared     = 0.6901
-------------+----------------------------------   Adj R-squared = 0.6613
       Total |  58.5715175        47  1.2462025     Root MSE      = .64972
```

```
           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0038613   .0007926     4.87   0.000     .0022629    .0054596
             |
   separator |
           2 |  -.2939419   .3016388    -0.97   0.335    -.9022545    .3143707
           3 |  -1.106205   .3050597    -3.63   0.001    -1.721416   -.4909931
           4 |  -1.770191   .2694339    -6.57   0.000    -2.313556   -1.226826
             |
       _cons |   -1.27903   .3188514    -4.01   0.000    -1.922055   -.6360047
```

Table 23: Regression outputs, Germany monthly – difference among size classes, year 2009, count (above) and capacity (below)

Source	SS	df	MS
Model	296.575215	4	74.1438037
Residual	22.3969914	42	.5332617
Total	318.972206	46	6.93417839

Number of obs = 47
F(4, 42) = 139.04
Prob > F = 0.0000
R-squared = 0.9298
Adj R-squared = 0.9231
Root MSE = .73025

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.005017	.0007193	6.98	0.000	.0035655	.0064685
separator						
2	-1.468638	.3139876	-4.68	0.000	-2.10229	-.834985
3	-3.392749	.3313203	-10.24	0.000	-4.061381	-2.724118
4	-.921156	.8514332	-1.08	0.285	-2.639418	.7971057
_cons	1.760043	.4869002	3.61	0.001	.7774391	2.742648

Source	SS	df	MS
Model	44.4848119	4	11.121203
Residual	22.2171417	42	.528979565
Total	66.7019537	46	1.45004247

Number of obs = 47
F(4, 42) = 21.02
Prob > F = 0.0000
R-squared = 0.6669
Adj R-squared = 0.6352
Root MSE = .72731

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0054176	.0007164	7.56	0.000	.0039719	.0068633
separator						
2	-.0377515	.3127244	-0.12	0.904	-.6688548	.5933517
3	-.3750303	.3299874	-1.14	0.262	-1.040972	.2909112
4	4.839129	.8480077	5.71	0.000	3.12778	6.550477
_cons	-2.955755	.4849413	-6.10	0.000	-3.934406	-1.977103

Table 24: Regression outputs, Germany monthly – difference among size classes, first half of year 2010, count (above) and capacity (below)

Source	SS	df	MS
Model	235.680543	4	58.9201357
Residual	46.3729601	25	1.8549184
Total	282.053503	29	9.72598285

Number of obs = 30
F(4, 25) = 31.76
Prob > F = 0.0000
R-squared = 0.8356
Adj R-squared = 0.8093
Root MSE = 1.362

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0111895	.0026979	4.15	0.000	.0056331	.016746
separator						
2	-.6610332	.856386	-0.77	0.447	-2.424793	1.102727
3	-1.59705	1.001464	-1.59	0.123	-3.659603	.4655028
4	5.933787	3.113824	1.91	0.068	-.4792524	12.34683
_cons	-4.036205	2.240369	-1.80	0.084	-8.65033	.5779205

Source	SS	df	MS		Number of obs =	24
					F(4, 19) =	20.28
Model	69.8637003	4	17.4659251		Prob > F =	0.0000
Residual	16.3641824	19	.86127276		R-squared =	0.8102
					Adj R-squared =	0.7703
Total	86.2278828	23	3.74903838		Root MSE =	.92805

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0198674	.0023882	8.32	0.000	.0148689	.024866
separator						
2	1.812641	.6142254	2.95	0.008	.5270524	3.09823
3	3.396501	.7671184	4.43	0.000	1.790904	5.002098
4	19.04053	2.559897	7.44	0.000	13.6826	24.39845
_cons	-15.4617	1.958123	-7.90	0.000	-19.5601	-11.3633

Table 25: Regression outputs, Germany monthly – difference among size classes, second half of year 2010, count (above) and capacity (below)

Source	SS	df	MS		Number of obs =	24
					F(4, 19) =	47.71
Model	133.687551	4	33.4218877		Prob > F =	0.0000
Residual	13.3102246	19	.700538135		R-squared =	0.9095
					Adj R-squared =	0.8904
Total	146.997776	23	6.39120763		Root MSE =	.83698

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0216542	.0041608	5.20	0.000	.0129456	.0303629
separator						
2	-.0254489	.6559565	-0.04	0.969	-1.398382	1.347484
3	.462339	.9862878	0.47	0.645	-1.601985	2.526663
4	15.51998	4.152606	3.74	0.001	6.828478	24.21149
_cons	-8.151585	2.484285	-3.28	0.004	-13.35125	-2.951917

Source	SS	df	MS		Number of obs =	24
					F(4, 19) =	9.18
Model	25.2176805	4	6.30442012		Prob > F =	0.0003
Residual	13.0425939	19	.686452313		R-squared =	0.6591
					Adj R-squared =	0.5873
Total	38.2602744	23	1.66349019		Root MSE =	.82852

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0228797	.0041188	5.56	0.000	.0142591	.0315004
separator						
2	1.604495	.6493283	2.47	0.023	.2454351	2.963555
3	3.750633	.9763217	3.84	0.001	1.707168	5.794098
4	22.46732	4.110645	5.47	0.000	13.86364	31.071
_cons	-13.389	2.459182	-5.44	0.000	-18.53613	-8.241871

Table 26: Regression outputs, Germany monthly – difference among size classes, year 2011, count (above) and capacity (below)

Source	SS	df	MS
Model	310.803256	4	77.7008139
Residual	27.6001268	43	.641863415
Total	338.403383	47	7.20007197

Number of obs = 48
F(4, 43) = 121.06
Prob > F = 0.0000
R-squared = 0.9184
Adj R-squared = 0.9109
Root MSE = .80116

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0080152	.0009686	8.27	0.000	.0060618	.0099686
separator						
2	-1.581053	.3394949	-4.66	0.000	-2.26571	-.8963965
3	-2.539445	.3687251	-6.89	0.000	-3.283051	-1.79584
4	.0559053	.8536916	0.07	0.948	-1.665728	1.777538
_cons	.7528582	.5493929	1.37	0.178	-.3550981	1.860815

Source	SS	df	MS
Model	51.9459725	4	12.9864931
Residual	46.4628202	43	1.0805307
Total	98.4087927	47	2.0938041

Number of obs = 48
F(4, 43) = 12.02
Prob > F = 0.0000
R-squared = 0.5279
Adj R-squared = 0.4839
Root MSE = 1.0395

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0082122	.0012567	6.53	0.000	.0056778	.0107467
separator						
2	-.0112647	.4404844	-0.03	0.980	-.8995861	.8770566
3	.5852361	.4784097	1.22	0.228	-.379569	1.550041
4	5.930949	1.107639	5.35	0.000	3.697182	8.164716
_cons	-3.893852	.7128207	-5.46	0.000	-5.331392	-2.456312

Table 27: Regression outputs, Czech Republic monthly – difference among size classes, year 2008, count (above) and capacity (below)

Source	SS	df	MS
Model	83.8251235	4	20.9562809
Residual	14.0993885	30	.469979616
Total	97.924512	34	2.88013271

Number of obs = 35
F(4, 30) = 44.59
Prob > F = 0.0000
R-squared = 0.8560
Adj R-squared = 0.8368
Root MSE = .68555

y	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
x	.0070187	.0015424	4.55	0.000	.0038687	.0101687
separator						
2	-2.87875	.3377445	-8.52	0.000	-3.568516	-2.188983
3	-3.590752	.3061675	-11.73	0.000	-4.216029	-2.965475
4	-3.802999	.3707311	-10.26	0.000	-4.560133	-3.045865
_cons	-5.59885	1.647866	-3.40	0.002	-8.964242	-2.233459

```
      Source |       SS       df       MS              Number of obs =       35
-------------+------------------------------           F(  4,    30) =    17.76
       Model | 43.1939695      4  10.7984924           Prob > F      =   0.0000
    Residual | 18.241553      30  .608051767           R-squared     =   0.7031
-------------+------------------------------           Adj R-squared =   0.6635
       Total | 61.4355225     34  1.80692713           Root MSE      =  .77978
```

```
           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0088381   .0017544     5.04   0.000     .0052552    .0124211
             |
   separator |
           2 |  -.7098015   .3841662    -1.85   0.075    -1.494373    .0747705
           3 |   .4598964    .348249     1.32   0.197    -.2513228    1.171116
           4 |   2.036381   .4216866     4.83   0.000     1.175182     2.89758
             |
       _cons |   -12.8315   1.874359    -6.85   0.000    -16.65945   -9.003548
```

Table 28: Regression outputs, Czech Republic monthly – difference among size classes, year 2009, count (above) and capacity (below)

```
      Source |       SS       df       MS              Number of obs =       45
-------------+------------------------------           F(  4,    40) =   131.82
       Model | 156.436411     4  39.1091027           Prob > F      =   0.0000
    Residual | 11.8671594     40  .296678985           R-squared     =   0.9295
-------------+------------------------------           Adj R-squared =   0.9224
       Total | 168.30357      44  3.82508114           Root MSE      =  .54468
```

```
           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0132426   .0009239    14.33   0.000     .0113752    .0151099
             |
   separator |
           2 |   -2.68963   .2240233   -12.01   0.000    -3.142398   -2.236862
           3 |  -3.393175   .2230658   -15.21   0.000    -3.844007   -2.942342
           4 |   2.600768   .4984204     5.22   0.000     1.593423    3.608114
             |
       _cons |  -19.99125   1.601768   -12.48   0.000    -23.22854   -16.75396
```

```
      Source |       SS       df       MS              Number of obs =       45
-------------+------------------------------           F(  4,    40) =   109.22
       Model | 129.379468     4  32.3448669           Prob > F      =   0.0000
    Residual | 11.8462457     40  .296156143           R-squared     =   0.9161
-------------+------------------------------           Adj R-squared =   0.9077
       Total | 141.225713     44  3.2096753            Root MSE      =   .5442
```

```
           y |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           x |   .0144144   .0009231    15.61   0.000     .0125487    .0162801
             |
   separator |
           2 |   -.602327   .2238258    -2.69   0.010    -1.054696   -.1499581
           3 |   .5239602   .2228692     2.35   0.024     .0735247    .9743956
           4 |   9.006392    .497981    18.09   0.000     7.999935    10.01285
             |
       _cons |  -27.06783   1.600356   -16.91   0.000    -30.30227   -23.83339
```

Table 29: Regression outputs, Czech Republic monthly – difference among size classes, year 2010, count (above) and capacity (below)

Source	SS	df	MS			
Model	105.065268	4	26.266317			
Residual	25.0291489	43	.582073231			
Total	130.094417	47	2.76796632			

Number of obs = 48
F(4, 43) = 45.13
Prob > F = 0.0000
R-squared = 0.8076
Adj R-squared = 0.7897
Root MSE = .76294

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0109451	.0014912	7.34	0.000	.0079377	.0139524
separator						
2	-1.75182	.3147591	-5.57	0.000	-2.386593	-1.117048
3	-2.444742	.3121991	-7.83	0.000	-3.074351	-1.815133
4	-1.992048	.3683775	-5.41	0.000	-2.734952	-1.249144
_cons	-18.25072	2.97656	-6.13	0.000	-24.25353	-12.24792

Source	SS	df	MS			
Model	94.1018921	4	23.525473			
Residual	28.4003034	43	.660472173			
Total	122.502195	47	2.60642969			

Number of obs = 48
F(4, 43) = 35.62
Prob > F = 0.0000
R-squared = 0.7682
Adj R-squared = 0.7466
Root MSE = .81269

y	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
x	.0128669	.0015885	8.10	0.000	.0096635	.0160704
separator						
2	.0411065	.335287	0.12	0.903	-.6350641	.7172772
3	1.259918	.33256	3.79	0.000	.5892471	1.93059
4	3.85822	.3924023	9.83	0.000	3.066865	4.649575
_cons	-26.86026	3.170685	-8.47	0.000	-33.25456	-20.46596

Appendix D: Content of Enclosed DVD

There is a DVD enclosed to this thesis which contains empirical data and models used in preparation of this thesis.

- Folder 1: Data (data on installations in Germany, UK and the Czech Republic)

- Folder 2: Model (MS Excel part of the model along with outputs from STATA)