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Report on Work Package B-3 and B-4 of the ETSAP Project "Integrating policy instruments into the TIMES Model"

# The modelling of regulatory instruments and financial incentive measures in the buildings sector

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June 2013

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# 1. Introduction

The main objective of the project “Integrating policy instruments into the TIMES Model” consists in developing modelling strategies for the explicit representation of different types of policy instruments in energy system models. After discussing in detail the various issues arising when modelling support systems for renewable electricity as well as emission trading schemes in the previous reports, two instrument categories still need to be covered: regulatory instruments and financial incentive measures. Command-and-control instruments have for a long time played a dominant role in environmental policy and are still applied today in various sectors and for a variety of purposes. Financial incentives are usually implemented as complementary measures to reduce investment barriers or to facilitate the market introduction of new and innovative technologies. They can be provided in various forms, most importantly investment grants, soft loans and tax reliefs.

For the project at hand, it has been decided to draw upon application examples from the buildings sector to exemplify modelling approaches for both types of instruments. The buildings sector is responsible for almost 40 % of the EU's total energy consumption and for about a third of $CO_2$ emissions. In this sector, mandatory requirements are generally set for new and refurbished buildings, while voluntary measures that go beyond these obligations are often supported by subsidy schemes. Moreover, the common legal framework on climate policy instruments in the buildings sector that has been established in the EU makes it easier to transfer the German experience, which as usual is used as a case study in this report, to other national situations.

After describing the European policy framework and the specific policy instruments in Germany in Chapter 2, different modelling techniques for regulatory instruments in the buildings sector will be presented in Chapter 3. Using the example of mandatory efficiency standards specified in the German Energy Saving Ordinance, it will be pointed out that in many cases the best way to include regulatory obligations is to account for them in the exogenous scenario assumptions. If, however, the instrument is designed in a more flexible manner leaving the affected investor a variety of options to fulfil the requirements, this flexibility needs to be reflected in the modelling approach. This will be illustrated for the case of the German Renewable Energies Heat Act prescribing minimum renewable shares for heating and cooling.

Representing the effect of financial incentive measures in quantitative energy models is comparatively complex as in this case greater uncertainties have to be taken into account. The acceptance and utilization of financial support schemes does, especially in the demand sectors, not only depend on cost parameters, but is also determined by a large variety of factors describing consumer behaviour. In Chapter 4, simple modelling approaches for two typical types of financial incentive measures - investment grants and soft loans, will be presented. In general, it will be shown that the right balance between fixing assumptions exogenously and relying on the optimization calculus needs to be found.

# 2. Basis for the case study: policy measures in the buildings sector in Germany

## 2.1. The European policy framework

When analysing national instruments of energy and climate policy in Europe, EU legislation needs to be taken into account as it provides a harmonized policy framework and influences and induces measures on the national level. The various EU directives targeted at the buildings sector also make it easier to compare national policy instruments in that area and to transfer modelling approaches from one country to another. The following outline concentrates on the two focal issues of energy efficiency and the use of renewable energies.

***Energy efficiency***

In 2002, the European Commission has created the legal basis for improving energy efficiency in the buildings sector by means of Directive 2002/91/EC, the Energy Performance of Buildings Directive (EPBD, cf. EC 2002). It is centered on the following four key components:

- It provides a general framework for a harmonized methodology for calculating the integrated energy performance of buildings which each member state is to apply at national level.
- Each member country is required to introduce minimum standards on the energy efficiency of new buildings and existing ones (with a total useful floor area over 1000 $m^2$) that undergo major renovation[1]. However, the directive does not prescribe any minimum requirements on the strictness of these standards.
- For buildings that are newly constructed, sold or let an Energy Performance Certificate (EPC) needs to be made available as guidance to potential buyers or tenants.
- Furthermore, national regulations are to be implemented that ensure the periodic inspection of boilers and of air-conditioning systems.

With the aim to further strengthen the efforts to improve the energy performance of buildings, a revision of the EPBD has been effectuated in 2010 (cf. EC 2010). In addition to the stipulations already made 2002, it has been determined that member states are to develop national plans to increase the number of "nearly zero-energy buildings" and to ensure that by the end of 2020 all new buildings belong to that category. Apart from that, stronger emphasis is put on financial support mechanisms for building such that each member state is required to present an updated list of all support schemes every three years to the Commission which examines their effectiveness and offers recommendations. In addition, a methodology for calculating cost-optimal levels of minimum energy performance requirements has been developed (cf. EC 2012) which should be used as guidance when establishing the national

[1] Major renovations are defined as those where the total cost of renovation is more than 25 % of the value of the building or where more than 25 % of the building shell is subject to renovation.

standards. It has to be noted that all provisions of the EPBD apply both to residential and non-residential buildings.

The translation of the EPBD into national law presented a substantial challenge to most of the member countries. Various studies (cf. Papadopoulou et al. 2009, Spiekman 2010, Loga et al. 2008) show that the EPBD has influenced the national building legislation in Europe significantly. Many countries already had some sort of energy-related requirements implemented in their building regulations, but in hardly any country an integrated concept to assess the energy performance of the entire building existed. The introduction of Energy Performance Certificates also proved to be a novelty in most countries. By now, every member state has put some minimum energy efficiency standards for new and renovated buildings in place - however, extensive differences regarding the level of ambition of these requirements can be observed (cf. for example Spiekman und Klerks 2010).

***Renewable energies***

Apart from increasing energy efficiency, the Energy Performance of Buildings Directive highlights the use of renewable energies as one of the major strategies to reduce $CO_2$ emissions in the buildings sector. That is why in the methodology for calculating the integrated energy performance of buildings the positive influence of heating and electricity systems based on renewable energy sources is to be taken into account. Moreover, in the case of new buildings a feasibility study on the use of renewable energy supply systems is mandatory. In the definition of the “nearly zero-energy building” it is specified that the energy supply still required should originate to “a very significant extent” (cf. Article 2 of Directive 2010/31/EU, EC 2010) from renewable sources. Beyond that, no further requirements on the use of renewable energies in the buildings sector are laid down in the EPBD.

However, additional obligations have been specified in the directive on the promotion of the use of energy from renewable sources (Directive 2009/28/EC, cf. EC 2009). By the end of 2014, national building regulations are to contain, as far as appropriate, requirements on the minimum use of renewable energies in new and existing buildings that are subject to major renovations. In order to reach the overall goal of a renewable share of 20 % in gross final energy consumption by 2020, member states have compiled national action plans on the expansion of renewable energy sources that define overall target values and specific ones for the areas electricity, heating/cooling as well as mobility for 2020. Figure 2-1 gives an overview on the renewable shares in gross final energy consumption for heating and cooling in 2005 and the national targets for 2020. It becomes apparent that there is an immense variation in the intended levels for 2020 ranging from less than 9 % in Luxembourg and the Netherlands to 62 % in Sweden. The most significant expansion rates are planned in Great Britain, albeit from the lowest comparative level in 2005 of less than 1 %.

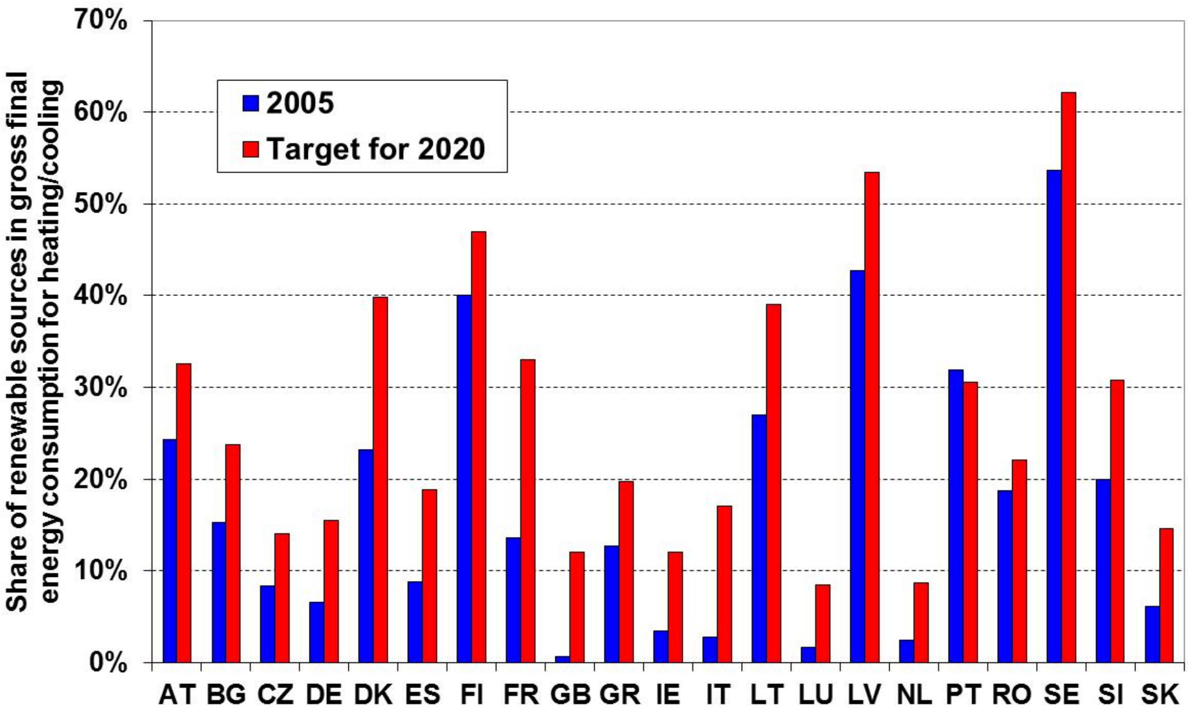


**Figure 2-1:** Renewable share in gross final energy consumption for heating and cooling in 2005 and targets for 2020 according to the national renewable energy action plans in the EU-27[2]

Across Europe, a variety of instruments has been introduced in recent years to support the expansion of renewable energies in the buildings sector. The number of countries that have implemented regulatory measures, i.e. in the form of mandatory standards on the minimum level of renewable sources used for heating and cooling, is rising. In many South European countries these requirements are usually limited to the installation of solar panels for hot water supply (for example Italy (cf. Zinzi et al. 2009), Spain (cf. Gobierno de España 2009) or Portugal (cf. Abreu und Oliveira 2008)) whereas in other countries, like Germany, Norway (cf. Schild 2010), Switzerland (cf. EnDK 2008) or Ireland (cf. Government of Ireland 2008), more comprehensive provisions where the investor can choose between different types of renewable energies have been established.

Apart from regulatory instruments, in most of the EU member states financial incentive measures are provided to encourage the use of renewable energies for heating and cooling. While mandatory provisions generally only apply to new buildings and existing ones undergoing major renovation, subsidy schemes are usually targeted at voluntary measures in existing buildings for which no obligatory standards have been specified. A differentiation can be made between investment grants funding energy consultancy services, feasibility studies or the installation itself, tax incentives in the form of a reduced value added tax, tax credits or special depreciation schemes as well as low-interest loans.

2 Cf. the national renewable energy action plans on http://ec.europa.eu/energy/renewables/action_plan_en.htm

## 2.2. Regulatory measures for energy savings in the buildings sector in Germany

In Germany, minimum requirements with respect to the insulation level and heating technology in buildings are laid down in the Energy Saving Ordinance (Energieeinsparverordnung, EnEV). Its first version entered into force in 2002 superseding the Thermal Insulation Ordinance (effective since 1979) and the Heating System Ordinance (effective since 1989). The Energy Saving Ordinance was last revised in 2009 (EnEV 2009, cf. Bundesgesetzblatt 2009) further tightening the standards on the permitted annual primary energy demand of buildings to a considerable extent.

The requirements of the EnEV consider both the structural heat insulation of the building envelope and the efficiency of the systems engineering (heating system, lighting, cooling, etc.). In addition, with the help of the primary energy factor, the utilized energy carrier and the associated $CO_2$ emissions are taken into account. Two methods are available to assess whether the EnEV standards are complied with which are used both for new and existing buildings undergoing major renovation. Based on the *reference building method* (cf. DIN V 18599) the primary energy demand of the planned building is calculated. Certification is provided if this demand is lower than the maximum permissible value of a reference building which is similar in terms of geometry, net floor space, orientation and utilization. In the case of residential buildings, the *building component method* (based on DIN V 4108-6 and DIN V 4701-10) can be applied alternatively which defines minimum standards for individual components. Table 2-1 shows the requirements of EnEV 2009 for the components of the building envelope, specified as maximum values of the heat transfer coefficient.

**Table 2-1:** Maximum values for the heat transfer coefficient according to EnEV 2009 (own illustration based on Bundesgesetzblatt 2009)

| ***Heat transfer coefficient U [W/(m²K)]*** | **New buildings (room temperature ≥ 19 °C)** | **Existing buildings (room temperature ≥ 19 °C)** | **Non-residential buildings (room temperature 12 to < 19 °C)** |
|---|---|---|---|
| Exterior walls | 0.28 | 0.24[a)] | 0.35[a)] |
| Windows (glazing+frame) | 1.30 | 1.30[b)] | 1.90[c)] |
| Roof / ceilings | 0.20 | 0.24[d)] | 0.35[d)] |
| Cellar ceilings / ceilings adjacent to unheated rooms or soil | 0.35 | 0.30[e)] | 0.35 / no requirements |

a) For existing buildings: exterior walls, replaced or retrofitted; renovation of exterior rendering with U>0.9 W/(m²K); attachment of panels, casing, masonry facing formwork, external insulation.

b) External windows and French doors, replaced or retrofitted; for glazing U=1.10 W/(m²K) applies, for roof windows U=1.40 W/(m²K).

c) External windows and French doors, replaced or retrofitted; no requirements in the case of glazing.

d) For existing buildings: ceilings, roofs and pitched roof areas, ceilings beneath undeveloped attic space replaced or retrofitted; for flat roofs U=0.20 W/(m²K) applies (in the case of room temperature ≥ 19 °C).

e) Walls and ceilings adjacent to unheated rooms or soil; replacement or retrofit of external insulation, casing, moisture barriers or drainages; attachment of ceiling coverings on the cold side; for floor constructions U=0.50 W/(m²K) applies.

The process for the next revision of the Energy Saving Ordinance has already been initiated and is planned to enter into force in 2014 (cf. BMWi 2013). The minimum standards for the annual primary energy consumption of new buildings will be further tightened in two steps, each of 12.5 %, in 2014 and 2016, while no significant changes are implemented for existing buildings subject to major renovations. Moreover, the obligations regarding the Energy Performance Certificate are reinforced.

### 2.3. Regulatory measures for renewable energies in the buildings sector in Germany

With the Renewable Energies Heat Act (Erneuerbare-Energien-Wärmegesetz (EEWärmeG), cf. Bundesgesetzblatt 2008) a regulatory instrument to increase the use of renewable energies in the buildings sector has been introduced in Germany. It came into effect on the 1st of January 2009 and applies to all new residential and non-residential buildings for which a building application or construction notification was filed after this date.

The act obliges owners of new buildings to cover a certain part of their heat (and cold) demand through renewable energies. However, no limitations are made regarding the type of renewable source employed such that each investor can choose the most cost efficient measure for his specific case. Dependent on the type of energy, minimum shares in total energy demand for heating and cooling (according to DIN V 4701-10) are defined:

- 15 % in the case of solar radiation,
- 30 % in the case of biogas in CHP installations,
- 50 % in the case of liquid and solid biomass,
- 50 % in the case of geothermal energy and ambient heat.

In addition, a number of alternative measures are granted which can be chosen in place of renewable sources:

- Covering at least 50 % of total heat and cold demand from installations for the use of waste heat or from high-efficiency CHP installations,
- Realizing additional energy savings measures that go beyond the minimum requirements of the Energy Saving Ordinance (in the version applicable at the time) by at least 15 %,
- Covering total heat and cold demand from district heat (or cold), provided that a "substantial share" originates from renewable energies, or at least 50 % originate from the use of waste heat, CHP installations or a combination of the just mentioned.

The obligations on the use of renewable energies and the alternative measures can be combined with one another in any way possible. In 2011, the Renewable Energies Heat Act has been amended with the major change consisting in the extension of the requirements to existing public buildings undergoing major renovation[3]. On federal level, so far no obligations are imposed on the remaining housing stock. However, the federal states are free to implement additional provisions, as has been the case in Baden-Württemberg (cf. Landtag BW 2007).

[3] In this context, major renovations are defined as any measure by which the boiler or heating system is replaced or more than 20 % of the building envelope is renovated.

## 2.4. Financial incentives for energy savings in the buildings sector in Germany

For several years now, energy savings measures in the buildings sector have been promoted by means of low-interest loans (complemented in some cases by investment or redemption grants) financed by federal funds and administered by the KfW banking group (Kreditanstalt für Wiederaufbau). In the following, the two most important programmes are outlined - *Energy Efficient Renovation* (“Energieeffizient Sanieren”) and *Energy Efficient Construction* (“Energieeffizient Bauen”). In general, support is only granted for measures that go beyond the minimum requirements of the Energy Saving Ordinance.

The programme *Energy Efficient Renovation* (cf. KfW 2013a) is based on previous programmes with similar focus that have been in place since 2001 and supports energy efficient refurbishment measures in existing residential or non-residential buildings. Soft loans can be used either for specific measures (e.g. insulating walls or ceilings, replacing windows, replacing boilers, etc.) or a complete renovation reaching the standards of the different types of “Energy-efficient buildings” defined in the Energy Saving Ordinance. In the first case, loans of up to 50,000 € are provided, while in the second case a loan volume of up to 75,000 € is combined with redemption grants of up to 17.5 %, depending on the energy efficiency standard. The loan may cover the actual investment costs as well as costs for energy consultancy services and planning. The programme covers all buildings with a building application issued prior to 1995 and is available for investors in energy savings measures as well as first buyers of newly refurbished flats or houses. The effective interest rate is currently set at 1 % p.a. (cf. KfW 2013e). As an alternative to a soft loan, private investors can apply for investment grants of up to 5,000 € in the case of specific measures and up to 18,750 € in the case of a complete renovation (cf. KfW 2013b).

From 2001 to 2010, a total of 1.3 million flats have been renovated under the *Energy Efficient Renovation* programme and its predecessors providing about 28.5 billion € in loans and grants with 7.2 billion € of federal funds (cf. Table 2-2). For the period from 2012 to 2014, the maximum federal funds available have been raised to 1.5 billion € per year, compared to 936 million € in 2011 (cf. BMU 2011).

**Table 2-2:** Key parameters for the KfW loan programme *Energy Efficient Renovation* and its predecessors (based on UBA 2013)

| | | **2001** | **2005** | **2008** | **2009** | **2010** | **2001-2010** |
|---|---|---|---|---|---|---|---|
| **Federal funds** | M € | 200 | 287 | 1128 | 1702 | 1127 | **7241** |
| **Credit volume** | M € | 507 | 2312 | 3850 | 5670 | 4945 | **28180** |
| **Grants** | M € | - | - | 27 | 99 | 147 | **288** |
| **Renovated dwellings** | thou. | 31.5 | 69.9 | 134.3 | 310.1 | 343.5 | **1329** |
| **Renovated dwelling area** | M $m^2$ | 2.6 | 6.4 | 11.6 | 27.6 | 29.4 | **112** |

As far as new buildings are concerned, financial incentives are provided through the KfW loan programme *Energy Efficient Construction* (cf. KfW 2013c) for highly energy efficient buildings. Low-interest loans of up to 50,000 € are available which can be complemented by redemption grants of up to 10 % in the case of more ambitious efficiency standards. At present, the effective interest rate amounts to 1.41 % per year.

From 2005 to 2011, about 400,000 energy efficient buildings have been built under this loan programme. In 2011, more than half of all newly built dwellings have received KfW loans with a total credit volume of 3.6 billion € (cf. UBA 2013).

## 2.5. Financial incentives for renewable energies in the buildings sector in Germany

With the aim to stimulate the market for renewable heating technologies, a financial incentive programme, open both for residential and non-residential buildings, has been introduced in 1999, the so called Market Incentive Programme (Marktanreizprogramm, MAP). The funding conditions have undergone several changes over the years, the most important being the limitation of most of the financial support to existing buildings that do not have to meet any obligations under the Renewable Energies Heat Act in 2010.

The programme consists of two lines:

- Investment grants for smaller installations, organized by the Federal Office of Economics and Export Control (BAFA)
- Low-interest loans and redemption grants for larger installations or infrastructures through the KfW banking group

The first part covers solar thermal installations and biomass heating systems with a rated heat output capacity of up to 100 kW as well as heat pumps for single- and multi-family houses, commercial and public buildings. An overview on the grant levels as of August 2012 is presented in Table 2-3. In addition, a number of bonus payments are available (cf. BAFA 2012).

Under the second programme line, the following larger installations for renewable heat generation are supported through soft loans and, in some cases, redemption grants (cf. KfW 2013d):

- Construction and expansion of solar thermal installations (gross collector area ≥ 40 $m^2$)
- Installations for the combustion of solid biomass for thermal use as well as biomass CHP plants (heat led) with a rated heat output capacity of more than 100 kW (and less than 2 MW in the second case)
- Efficient heat pumps with a rated heat output capacity of more than 100 kW
- Installations for the exploitation of deep geothermal energy (drilling depth ≥ 400 m)
- Large heat storage systems (≥ 10 $m^3$) which are fed to a substantial degree from renewable energy sources
- Local heat grids which are fed to a substantial degree from renewable energy sources
- Biogas pipelines for unprocessed biogas for usage in a CHP plant or as fuel

The loan may cover up to 100 % of total eligible net investment costs, but not more than 10 million €. At present, effective interest rates range between 1.15 and 6.45 % (cf. KfW 2013e).

**Table 2-3:** Current investment grants under the Market Incentive Programme, Line 1 (based on BAFA 2012)

| Heating technology | Subsidy level |
|---|---|
| **Solar thermal installations** | |
| ≤ 40 $m^2$ gross collector area | 1500 - 3600 € |
| 20 - 100 $m^2$ gross collector area in multi-family houses and large non-residential buildings (also existing ones) | 3600 - 18000 € |
| ≤ 1000 $m^2$ gross collector area for the generation of process heat | Up to 50 % of net investment cost |
| **Biomass heating systems** | |
| Pellet stove with water jacket | 1400 - 3600 € |
| Pellet boiler | 2400 - 3600 € |
| Pellet boiler with buffer storage (≥ 30 l/kW) | 2900 - 3600 € |
| Wood chip boiler with buffer storage | 1400 € |
| Firewood gasification boiler with buffer storage | 1400 € |
| **Heat pumps** | |
| Brine/water and water/water heat pump | 2800 - 11800 € |
| Brine/water and water/water heat pump with buffer storage | 3300 - 12300 € |
| Air/water heat pump | 1300 - 1600 € |
| Air/water heat pump with buffer storage | 1800 - 2100 € |

Table 2-4 shows how the funding and investment volumes of projects funded under the Market Incentive Programme have developed in recent years. In terms of investment grants for smaller installations (programme line 1), 2009 presented a record year. Afterwards, the funding volume dropped considerably due to the fact that installations in new buildings were no longer supported. The loan volume under programme line 2 has risen constantly until 2011.

**Table 2-4:** Funding and investment volume under the Market Incentive Programme (based on Langniß et al. 2010, Langniß et al. 2011, BMU 2012a, BMU 2012b)

| Mio. € | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|
| Programme line 1 (BAFA) | | | | |
| Sum of investment grants | 374 | 235 | 112 | 144 |
| Induced investment volume | 2746 | 1808 | 804 | 963 |
| Programme line 2 (KfW) | | | | |
| Loan volume | 298 | 329 | 503 | 365 |
| Sum of redemption grants | 90 | 100 | 168 | 113 |

# 3. Modelling of regulatory instruments in the buildings sector

## 3.1. Modelling of efficiency standards - the example of the Energy Saving Ordinance

In order to reduce the heating demand in the buildings sector, efficiency standards, normally applying to new buildings and existing ones subject to major renovation, have been incorporated into national building regulations over the past few decades. Based on the example of the German Energy Saving Ordinance (EnEV) it will be shown that in this case the simplest and most efficient way of accounting for this instrument in an energy system model is to integrate its impacts in the exogenously set heating demand.

When the objective consists in assessing the impact of mandatory efficiency standards in the buildings sector, it is necessary to analyse in a first step the characteristics of the housing stock as well as the expected construction activity of new buildings itself. In this process, a building typology is developed. Here, the buildings are classified by building types (multi-family houses, terraced houses, detached houses, etc.) and time of construction. Buildings belonging to a certain age category are usually comparable in terms of building materials, design of the building envelope, dimensioning of the building elements, etc. and exhibit therefore also similar specific heating demands. For example, in Germany a clear differentiation can be made between buildings built before 1979 - when the first Thermal Insulation Ordinance entered into force - and after. In addition, regional differences should be taken into account, as, for example, the clearly divergent characteristics of the housing stock in Western and Eastern Germany. On this basis, a representative building is assigned to each building type for which the specific space heating demand is calculated per square metre of usable living space. In addition, the heating requirement for hot water needs to be considered, which mainly depends on the number of persons living in a household.

Furthermore, in the case of existing buildings being refurbished the impact of minimum requirements on energy efficiency strongly depends on the annual refurbishment rate. In Germany, it currently amounts to about 1.1 % per year, while for the future the German Energy Concept aims at a rate of 2 % p.a. The refurbishment rate could be determined endogenously within the energy system model by integrating different types of renovation measures into the model. However, it has to be kept in mind that the number of buildings renovated each year is influenced by a variety of factors and is subject to significant investment barriers. Consequently, an endogenous optimization of the refurbishment rate is likely to result in a considerable overestimation of the actual renovation activity. That is why, in the scope of this analysis, it is recommended to set the refurbishment rate exogenously, based on the historical development. In addition, a sensitivity analysis with varying rates can be conducted.

The next step consists then of integrating the efficiency standards of the Energy Saving Ordinance into the model. This can be done by directly incorporating the minimum obligations into the heating demand projections of the different building types (expressed as specific heating requirement per unit of building volume or area to be heated). In doing so, it needs to be taken into account that the requirements specified in the Ordinance can be expected to be tightened periodically. As an example, projections for the minimum efficiency standards for residential buildings, expressed as maximum values for the heat transfer coefficient of individual building components, are presented in Table 3-1.

**Table 3-1:** Projections for the minimum efficiency standards for residential buildings specified in the German Energy Saving Ordinance (EnEV)

| ***Heat transfer coefficient U [W/(m²K)]*** | **EnEV 2007** | **EnEV 2009** | **EnEV 2014/16** | **EnEV 2020** | **Projection to 2050** |
|---|---|---|---|---|---|
| Exterior walls | 0.35/0.45 | 0.28 | 0.24 | 0.14 | 0.10 |
| Windows (glazing+frame) | 1.70 | 1.30 | 0.80 | 0.70 | 0.50 |
| Roof / ceilings | 0.30 | 0.24 | 0.15 | 0.13 | 0.10 |
| Cellar ceilings / ceilings adjacent to unheated rooms or soil | 0.40 | 0.35 | 0.20 | 0.16 | 0.16 |

Thus, in the case of mandatory efficiency standards in the buildings sector the most convenient method of integrating them into the model is to take them into consideration when fixing the exogenous heat demand projections. It would be much more complex to integrate all necessary refurbishment measures (for the case of renovated existing buildings) with additional processes into the model and at the same time no further information would arise from this procedure. Adjustments in the refurbishment rate or the new construction activity can be accounted for in a scenario variation.

However, one drawback of this simple approach needs to be mentioned at this point. When the obligatory efficiency standards are incorporated in the exogenous demand projections, the costs that are induced by this command-and-control policy are not included in the model and therefore not reflected in energy system costs. At the same time, the cost savings generated by the higher energy efficiency are considered in the model. An easy way to address this issue would be to add these extra costs, which can be calculated by comparing the efficiency level and the associated investments with and without the mandatory efficiency standards in place, exogenously after the model calculations to the results on total energy system costs.

Alternatively, a relatively complex method with which all efficiency measures are represented endogenously within the model can be applied. In this case, the heating demand projections for the different building types would reflect the development of the efficiency level that would arise if the Energy Saving Ordinance or any other mandatory standards were not implemented. All the efficiency measures that can be applied to fulfil the minimum requirements both in existing buildings undergoing major renovations and new ones are then inserted into the model with the help of saving processes which are explained and exemplified in greater detail in Chapter 4.2. These processes contain the energy savings which can be achieved with the various efficiency measures and also the associated costs such that they are directly included in total energy system costs. In order to reflect the impact of the obligatory efficiency standards, the use of these saving processes would have to be forced into the model with the help of lower bounds or user constraints. This approach improves the transparency of the modelling of mandatory efficiency requirements in the buildings sector and also makes sure that all additional costs are covered in the model and no cost terms have to be added exogenously after the model calculations. At the same time, this method strongly increases the complexity of the modelling approach for such efficiency standards.

## 3.2. Modelling of minimum requirements for renewable energies - the example of the Renewable Energies Heat Act

As outlined in Chapter 2.1, apart from mandatory efficiency standards minimum requirements for the use of renewable heating technologies gain in importance across Europe. How such regulations can be depicted in a realistic manner in energy system modelling will be outlined in the following using the example of the German Renewable Energies Heat Act.

Generally, as it was the case for efficiency standards, the representation of regulatory requirements for renewable heat in the buildings sector in an energy system model is relatively straightforward and can be achieved with the help of fixing lower bounds or user constraints. Looking at the Renewable Energies Heat Act or other comparable instruments in Europe, it becomes, however, obvious that modelling real-life implementations of such instruments can become much more complex. The German Renewable Energies Heat Act offers affected investors in new buildings a large variety of choices to fulfil the requirements - covering both a number of renewable heating technologies and some alternative measures. This flexibility needs to be accounted for in the model.

In principle, two options to integrate these choices in the modelling approach can be differentiated. First of all, one might determine the future shares of the different heating technologies and alternative measures in new buildings exogenously and then introduce them into the model in a fixed manner. This procedure is currently applied in a number of simulation models (cf. BMU 2012c, Nast et al. 2009). In an optimization model like TIMES, the other extreme would be to leave the technology choice completely to the optimization calculus. This would, however, mean that the alternatives are chosen only based on the criteria of cost minimization most probably resulting in a concentration on only one heating technology type per building category. Yet, in reality, technology choice is dependent on a large variety of determinants, like consumer preferences, level of information, specific characteristics of the building or location, etc. All these factors cannot be represented in the necessary level of detail in a comprehensive model like TIMES. In order to avoid unrealistic outcomes while at the same time maintaining a certain level of flexibility in the model, an approach balancing both extremes (completely exogenously vs. completely endogenously) is proposed in the scope of this analysis.

In order to model instruments like the Renewable Energies Heat Act, in the first step one has to make sure that all technology options and alternative measures are available in the model. Furthermore, housing categories should be present in the model for all new buildings types constructed from the model period in which the regulation was implemented onwards. The minimum obligations for the use of renewable heat can then be easily introduced in the model by only providing the options covered by the Renewable Energies Heat Act to those building categories. At the same time, it has to be ensured, that all realistic options to combine the requirements from the Act with conventional heating technologies are available in the model, as the mandatory minimum renewable shares do not go up to 100 %. This may lead to a relatively complex model structure, depending on the number of building categories included.

In a next step, some additional restrictions must be put on the model in order to avoid that only one renewable heating technology is installed per housing category. This can be realized by means of fixing upper and lower market shares for each technology option. It this way, it can be guaranteed both that the modelling results stay in a realistic range and that the model has enough scope and flexibility to react to changes in the scenario assumptions. The specification of the market shares should be based on a broad literature research, including both past developments and expected future changes in the building characteristics, the heating requirements, technology cost, etc.

This modelling approach can easily be adapted to changes in the regulatory requirements, like, for example for the case that the minimum shares for renewable heat are increased or that the requirements are extended to existing buildings in which the heating system is replaced.

# 4. Modelling of financial incentive measures in the buildings sector

## 4.1. Modelling of investment grants - the example of the Market Incentive Programme

The provision of investment grants can play an essential role in fostering the market introduction of new technologies and in reducing investment barriers. For the case study at hand, the German Market Incentive Programme (Line 1), offering subsidies for renewable heating technologies, is used to outline two different approaches, varying in complexity, for the modelling of investment grant schemes in energy system models.

The first approach is comparatively simple and has already been applied in some energy system analyses (cf. for example UBA 2013). It is based on exogenously estimating the future effects of the grant programme and then integrating these impacts with the help of user constraints into the model. For governmental support programmes, historical data from previous funding years is usually available at a very detailed level. For example, for the Market Incentive Programme, data on the sum of approved investment grants and the induced investment volume by heating technology and building category are published on a regular basis (cf. for example Langniß et al. 2011). This information can then be used to deduce future trends in the utilization and effects of the support scheme. It can be assumed, for example, that the future grant volume will remain at the level of previous years and that the distribution across technologies will also remain unchanged. In addition, expected changes in the investment cost structure for renewable heating systems can be taken into account when defining the shares of different technologies in the funding. Apart from that, it should be considered that the requirements for participating in the grant programme might be gradually tightened over time, specifying, for example, higher efficiency standards for heating systems based on biomass.

The thus determined investment volumes can then be introduced into the model with the help of user constraints or lower bounds on the new investments in these technologies in each modelling year. The reduced costs due to the governmental funding can also be integrated into the model simply by using lower specific investment cost (actual investment costs minus the grant payment) for these processes. At the same time, it has to be kept in mind that this will result in a reduction of total energy system cost such that the programme cost (including administrative cost) would have to be stated separately and added to the model calculations on total energy system costs when evaluating the policy's impact.

As an alternative, a second modelling approach can be used which tries to assess the impact of such a grant programme in an endogenous manner and is therefore more complex. Here, the investment subsidy is directly integrated into the model with the help of the TIMES parameters available to represent subsidies. One way of achieving this is to introduce an additional process subsequent to the process representing the renewable heating technology (for existing buildings) (cf. Figure 4-1). This virtual process contains the investment grant (modelled with the parameter *NCAP_ISUB* which establishes a subsidy payment per unit of newly installed capacity). For the availability factor and the technical lifetime the same assumptions are used as for the actual heating process. The reason why an additional process is added instead of directly putting the subsidy parameter on the renewable heating process is to give more flexibility to the modelling structure. In this way, the renewable heating technology can be installed both with and without the investment grant. This is particularly relevant for the case that the total budget of the grant programme is depleted. Alternatively, all renewable heating technologies in the housing stock that are covered by the support scheme could be modelled twice - once with the investment grant and once without. This modelling approach leaves the decision whether, to what extent and for which technologies the investment grants are used to the optimization calculus of the model.

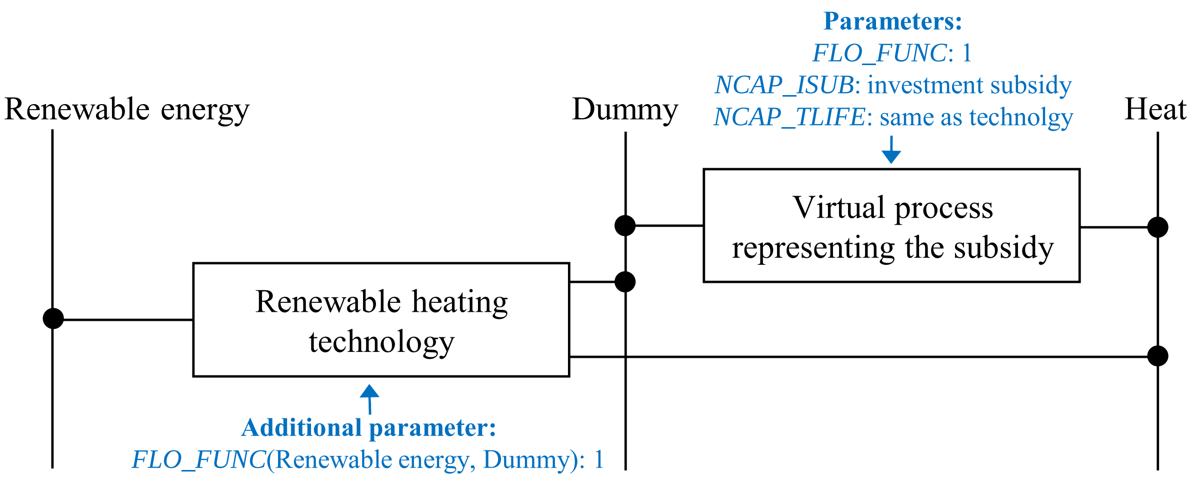


**Figure 4-1:** Modelling approach for investment grant programmes for renewable heating technologies in TIMES

Apart from integrating the investment grants into the model, it has to be kept in mind that the budget for this type of support programmes is usually limited and this cap needs to be adhered to in all modelling periods. There exist several possible ways of cost bounding in TIMES (cf. Lehtilä 2007). For the problem at hand, the utilization of a user constraint seems to be the most suitable option. In that way, either the total investment volume (using *UC_NCAP*) or directly the total grant budget (using in addition *UC_ATTR*) can be bounded without giving specific limitations for the different technologies.

Moreover, it has to be pointed out that when using the subsidy parameters in TIMES the origin of these funds is assumed to lie outside of the energy system. Thus, all subsidies enter the objective function with a negative sign, i.e. actually reduce energy system costs. Therefore, as it was the case for the first modelling approach, all programme costs need to be taken into account additionally when evaluating the cost efficiency of the support scheme.

## 4.2. Modelling of soft loans - the example of the KfW programmes

Subsidised loans with low interest rates are usually used to overcome financial barriers with respect to investments that are beneficial from a macroeconomic point of view. To illustrate how such loan programmes can be depicted in the scope of an energy system analysis, the current soft loan schemes provided through the KfW banking group for energy savings measures in the buildings sector that go beyond the minimum legal requirements are taken as an example.

When the aim is to model such programmes in an explicit manner, in a first step one has to make sure that all energy savings measures covered by the scheme are represented in the model. It has been shown in Chapter 3.1 that legally binding efficiency standards can be directly accounted for in the exogenously set demand projections without having to model the actual saving measures. For all additional measures that are realized on a voluntary basis, the explicit representation within the model is necessary. This can be done with the help of so-called saving processes, which are illustrated in a simplified manner in Figure 4-2. These processes are inserted into the model after the heat generation processes and can represent either specific saving measures (e.g. the replacement of windows) or a complete renovation - both for refurbishments in existing buildings and for investments in new buildings that go beyond the required minimum standards. They contain the average investment costs of such measures, while the actual energy saving is captured by applying a process efficiency (represented by *FLO_FUNC*) of greater than one. The technical lifetime of such a process should be the same as the average period of use of the respective building type.

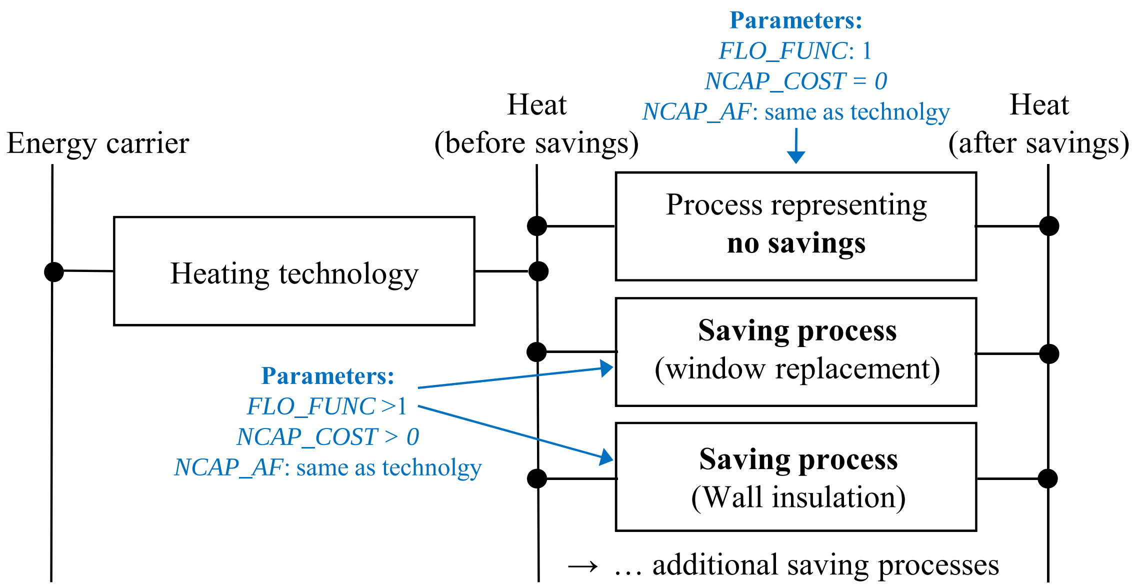


**Figure 4-2:** Modelling approach to represent energy savings measures with the help of saving processes in TIMES

At this point it needs to be pointed out that when using saving processes, the relationship between such processes and the elastic demand feature in TIMES should be taken into consideration. Own-price elasticities on the demand for space heating are often fixed at a level as to comprise such voluntary energy savings measures induced by price changes. So, by introducing both saving processes and elastic demands in the model the effect of potential energy savings measures could be overstated. In order to avoid this, price elasticity values should be clearly reduced to a level where they only comprise adjustments in the heating demand due to reduced comfort requirements (which can be assumed to be comparatively small) when inserting saving processes to represent energy savings measures into the model.

As an alternative, the heating demand could also be quantified in terms of “building volume (or area) to be heated”, instead of directly specifying the heating demand per unit of building area or volume. In that case, efficiency measures could then be inserted in the model after the actual heating generation technologies as processes reducing the specific heating requirement per unit of building area or volume.

Moreover, it has been observed that the level of thermal insulation a building has often influences the choice of heating system. So, in addition to the regular heating systems a second set of processes could be added that represent both the heating boiler and the improved level of thermal insulation (expressed by a higher process efficiency) and contains all associated costs. However, it has to be taken into consideration that this can quickly lead to a highly complex modelling structure as a large variety of combinations between heating system and efficiency measure needs to be taken into account if the same flexibility as in the case with saving processes is to be achieved. Furthermore, with the help of saving processes a more transparent model structure can be achieved.

After having integrated all potential energy savings measures for the different building categories, two different modelling approaches for introducing soft loan programmes into the model can be differentiated - analogous to the procedure applied for investment grant schemes.

One possibility would be to estimate the impacts of such schemes exogenously and then insert them into the model in a fixed manner (cf. for example UBA 2013). The future trends can be assessed on the basis of historical data. In the case of energy savings measures, particular attention needs to be paid to the fact that the minimum requirements that need to be fulfilled in order to have access to a soft loan programme can be expected to be raised in the future, just as the legally binding efficiency standards are tightened. The determined effects can then be integrated into the model with the help of lower bounds or user constraints on the saving processes. In addition, as it was the case for investment grant schemes, it needs to be pointed out that the programme costs should be accounted for in the evaluation of the cost efficiency of such a soft loan programme (generally outside of the model).

With the objective to analyse the utilization and effects of soft loan schemes for energy savings measures endogenously within the model, a second modelling approach can be applied. This is, however, not as straightforward as in the case of investment grant programmes, as low-interest loans do not directly lower the actual investment costs. So, instead of inserting additional cost terms into the model, the discount rates need to be addressed. It can be expected that the discount rate, representing the opportunity cost of capital, can be lowered with the help of soft loan schemes. To empirically verify the size of the effect is, however, extremely difficult. This is especially the case for demand sectors like private households where discount rates are usually used to represent a large variety of factors in addition to time preference and the actual cost of capital, like incomplete information, intangible cost, etc.

On this basis, in the scope of this analysis it can be concluded that lowering the discount rate for energy savings measures still is the most suitable way to integrate a soft loan programme into the model. It is, however, recommended to conduct a sensitivity analysis with a range of discount rates in order to assess the robustness of the results. In order to include both the option to realize a certain energy saving measure under the soft loan scheme and without it (once the programme funds are depleted), all saving processes are modelled twice, once with a reduced discount rate and once with the normal one. The programme budget is then limited by putting a user constraint on all saving processes with the lower discount rate. The present issue highlights once more that further research is needed on the discount rates used in energy system modelling.

## 5. Conclusion

The buildings sector will play an essential role in reducing greenhouse gas emissions - both because of its current significant share in $CO_2$ emissions and because of the high potential for comparatively cost efficient mitigation options that has been identified in this sector. At the same time, it has been observed that substantial investment barriers need to be overcome in order to realize this potential. Across Europe, two different types of policy instruments are usually implemented to address this issue. Regulatory instruments, prescribing minimum energy-related building standards, are usually applied to new buildings and existing ones undergoing major renovation. All additional measures that go beyond these mandatory requirements are often encouraged by some type of financial incentive measure. That is why the buildings sector provides a suitable case study to illustrate different modelling strategies with which these two types of policy instruments can be represented in an energy system model.

In theory, modelling regulatory instruments in quantitative energy models is relatively straightforward as any obligatory measure can be integrated with the help of bounds and user constraints. When looking at the actual regulations in the buildings sector, however, it becomes obvious that substantial challenges may arise with respect to the model integration. First of all, regulatory instruments often exhibit a high level of detail with the aim to offer appropriate and tailored measures to all different types of cases. This depth of detail may lead to a highly complex modelling structure or the necessity to make exogenous assumption and aggregate information in the model. Secondly, in order to render mandatory instruments more cost efficient, regulators usually try to offer a variety of choices which can be employed to fulfil the requirements. Thus, this additional flexibility should be accounted for in the model.

TIMES contains several types of subsidy parameters such that the necessary foundation for the modelling of financial incentive measures is given. However, relying solely on the optimization approach in determining the effects of programmes offering investment grants, soft loans, etc. might yield unrealistic model results. In reality, the decision to make use of a certain support programme depends on a large variety of factors, like available information, heterogeneous preferences, etc. Hence in a comprehensive model like TIMES, in which not all of these factors can be taken into account in detail, reasonable exogenous assumption reflecting the impact of the support programme need to be introduced into the model, while at the same time it is desirable to retain enough flexibility such that the optimization calculus can react to changes in the overall scenario assumptions.

Even though the present report uses specific instruments from Germany to exemplify the different modelling approaches, these techniques can be easily transferred to other countries due to the fact that the measures implemented in the buildings sector are usually quite comparable. It has to be noted that the level of detail with which a certain instrument is modelled always also depends on the type of model that is used, e.g. a comprehensive model covering the entire energy system or a partial model focusing on the buildings sector.

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