PATHWAYS project
Exploring transition pathways to sustainable, low carbon societies
Grant Agreement number 603942

Deliverable D2.1: Analysis of green niche-innovations and their momentum in the two pathways

Country report 4: Green niche-innovations in the German heat system

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Wuppertal Institute, 1 December 2014
Niche innovations in the heat domain
Case study Germany

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Executive Summary

This paper presents the current state and development of six niches in the German heat domain and evaluates the niches’ individual momentum and prospect with regard to upscaling. Specifically, small-scale residential biomass heating systems, district heating, heat pumps, solar thermal installations, low-energy housing and passive houses, and behaviour change campaigns/smart metering are investigated. All niches are analysed with regard to particular innovations or technologies, actor configurations, network constellations and the interplay of actors. Also, governmental influence is taken into regard. After that, each niche’s current momentum and future potential is evaluated based on the results of the aforementioned categories.

The findings show that the German heat domain has an overall stable actor configuration, but competition between the different systems and their respective actors (e.g. biomass, gas and heat-pumps) cater for a dispersed regime. Incumbent firms of existing technologies, many of them SMEs, are at least as important as new entrants and start-ups. Very important influences stem from the Federal Government and associated organizations like the Kreditanstalt für Wiederaufbau (KfW), Germany’s federal state bank for funding issues and subsidies. Other important decision makers are the homeowners. Units tend to be heated separately and the decision for the applied heating system thus lies with the individual proprietor. This underlines the decentralism and diversity of the incumbent regime, in which gas heating dominates. However, gas is by far not the only technology, and it also relies on a variety of appliances, e.g. gas networks vs. singular solutions, centralized/decentralized heating in building units, including/not-including warm water provision etc. The activities of the homeowners are also strongly affected by their relations to tenants (representing 72% of German households) and the possibility of handing over investment costs. Large associations representing owners and tenants, respectively, represent their partly contradicting interests, lobbying for certain changes or activities in legislation and funding of potentially green technologies.

With regard to the heating domain and its technologies a strong relation to the electricity domain became apparent which leads to a very interesting link to German efforts for renewable energies (known as the ‘Energiewende’). Some heat-related technologies, e.g. heat pumps and district heating require powering by renewables in order to have a CO₂-saving effect or positive environmental impact, while they may even be harmful when relying on conventional energy sources. Other technologies, most notably solar thermal installations, compete with renewable energies (in this case photovoltaics) and are thus hampered in their development. Overall, for the reasons mentioned, the German heat domain presents an unclear picture. Right now, it cannot be projected which appliances will eventually lead to a regime change, if a regime change will happen at all. Most niches analysed have been identified to belong to the Pathway A type with considerable technological advancement and potential but little required changes in overall configuration.
1 Introduction: Background and context of the heat domain

1.1 Initial sketch of the socio-technical system

The socio-technical heating system in Germany can be subdivided into two sections: heat demand and heat supply. Heat demand largely arises from the existing building stock, which may change over time due to construction of new buildings/replacement and refurbishment of old buildings as well as changes in consumer behaviour. Heat generation on the other side depends on the heating technologies in place. However, heating appliances (or infrastructures) can be replaced more easily than buildings and thus have typically lower life-times. The heat generation side may therefore undergo transitions at a higher pace than the demand side.

The target of this paper is to analyse, to which extent niche innovations may contribute to a low-carbon transition of the German heat domain. In Figure 1, we therefore identified the potential “green” niche technologies that may contribute to such a transition of the heat demand and supply system in Germany. The niche actors will be analysed in the respective niche sections of this study. Principal actors include the investors/owners of property, technology manufacturers, civil society organisations (such as environmental NGOs, owner/tenant associations) and district heat grid and plant operators. Important actors in the current heat generation domain are incumbent manufacturers of today’s German “standard” fossil fuel technologies and fuel providers. These will however not be investigated, as the analysis of niches is of interest.

Figure 1: Sketch of the German heat domain and principal actors

Note: this figure provides only a stylized overview of the German heat system.
Political actors at all levels (EU, national, local) are also of high importance for the momentum of the niche technologies as they shape the environment in which niches develop and compete with regime technologies.

1.2 Main characteristics and developments of the German heat domain

Buildings in Germany consume almost 40% of the country’s final energy consumption of about 9,2269 PJ. As of 2012, 68% of the final energy consumption of 2,431.5 PJ in residential buildings was used for space heating, the remaining 32% for water heating and other energy applications such as lighting, cooking etc. (BMWI 2014a, see Figure 2). The German residential heat domain therefore contributes a significant share of total energy consumption.

Figure 2: Final energy consumption in German private households (PJ)

![Figure 2](image)

Source: Data from BMWI 2014a

The heat demand of a building strongly depends on the building’s energy efficiency (insulation). Legal efficiency standards have been tightened since the 1980s and reach low-energy standards since the enactment of EnEV 2009 (see section 3.5). Figure 3 shows total residential building area by year of construction. About 70% of the building area has been constructed before the first building regulation (WSVO) in 1977, and about 95% before the enactment of the already relatively strict EnEV 2002. A large share of this old building stock has not been refurbished yet, which leaves a large potential for increasing the overall building energy efficiency.

In addition, over half of German buildings are rented (see Figure 4), sheltering 72% of all households (Destatis 2014). While owners take investments, occupants mostly profit from efficiency gains. In rented buildings, this generates diverging interests of the two main actors owners and tenants (split incentives-dilemma) and consequently refurbishment rates are generally lower in rented buildings than in owner-occupied buildings.
How the resulting heat demand is met depends on the technologies in place within buildings. Analysing the final energy consumption of private households by energy carriers (Destatis 2010, in absolute figures see Figure 5, in percentage see Figure 6) gives an impression of the main trends in this sector. Total final energy demand has remained stable over the last two decades in Germany. The dominating heating systems are still based on fossil fuels (gas, mineral oil and district heating which is mostly coal- or gas-based). “Green” systems such as biomass, geo- and solar thermal serve 10% of total heat demand.
A slight shift from mineral oil and lignite towards energy carriers with fewer environmental impacts such as gas has occurred since 1990. The major share of this shift has taken place in the aftermath of German re-unification and may thus be regarded as a historically special effect of replacing out-dated technologies in former East Germany. Furthermore, a small but steady trend towards biomass, solar and geo-thermal and heat pumps can be observed (AG Energiebilanzen 2013).
## 2 Case selection

### 2.1 Long list of potential green niche innovations

In a project workshop, a long list of potential niche innovation was drafted. Each niche innovation has initially been classified with regard to following Pathway A or B. Table 1 presents the long list and indicates which niche innovations were shortlisted (see following section 2.2).

### Table 1: Long and short list of niche innovations in Germany

<table>
<thead>
<tr>
<th>Category</th>
<th>Pathway A / B</th>
<th>Short List</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>renewable heating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>solar thermal heating (collectors)</td>
<td>A x</td>
<td>Relevant niche technology in Germany</td>
<td></td>
</tr>
<tr>
<td>solar hot water heaters</td>
<td>A</td>
<td></td>
<td>Partly included in solar thermal heating</td>
</tr>
<tr>
<td>waste water heat recovery</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>biomass heating systems (pellets)</td>
<td>A x</td>
<td>Technology traditionally used, but small niche today. Biomass with focus on pellets.</td>
<td></td>
</tr>
<tr>
<td>heat generation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>geothermal heating</td>
<td>B</td>
<td></td>
<td>Existing in Germany but marginal niche, excluded</td>
</tr>
<tr>
<td>district heating</td>
<td>A/B</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>virtual power plant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>insulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>insulation of hot water pipes</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>insulation of exterior walls, basement, roofs</td>
<td>A x</td>
<td>Analysis included in low-energy buildings</td>
<td></td>
</tr>
<tr>
<td>greening exteriors and roofs (also for cooling)</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ventilation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>efficient mechanical HVAC systems</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>energy efficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>efficient, condensing boilers</td>
<td>A</td>
<td></td>
<td>Already standard technology for new heating systems in Germany</td>
</tr>
<tr>
<td>heating control systems (smart meters)</td>
<td>B x</td>
<td>Heating smart meters not yet implemented, but potentially important niche</td>
<td></td>
</tr>
<tr>
<td>heat pumps</td>
<td>A</td>
<td>x</td>
<td>Niche technology gaining importance in new buildings, but necessity to assess potential and sustainability in Germany</td>
</tr>
<tr>
<td>behaviour change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lower indoor temperature (thermostats)</td>
<td>B x</td>
<td>Partly covered together with Smart metering, Needs societal behaviour change</td>
<td></td>
</tr>
</tbody>
</table>
lower size of dwelling per capita.

<table>
<thead>
<tr>
<th>Building standards</th>
<th>Low-energy, zero/passive-houses</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Needs societal behaviour change and potentially different technologies/architecture</td>
</tr>
<tr>
<td>x</td>
<td>Highly relevant niche, both for new and existing buildings. Due to large stock and low construction/refurbishment rates no narrow focus on passive houses.</td>
</tr>
</tbody>
</table>

2.2 Selection of 8 niche innovations

Discussions between the three heating cases (Sweden, Germany, UK) and WP2 leaders led to a joint assessment of most important niche innovations to be shortlisted for each country case in order to assess the most relevant niches and enable good opportunities for comparative research.

The main period of analysis covers the last decade (since 2000). This period was analysed as far as data was available, and if useful extended to a larger time period. The niches analysed cover the heat demand (buildings, smart metering) and the heat supply (various heat provision technologies). None of the identified niche technologies is entirely new to the German heat domain, however, their historic development, current market penetration and momentum varies significantly. Contrary to e.g. the Swedish case, a transition of the heat domain has yet not taken place in Germany, but has only started.

The niches selected from the long list in section 2.1 to be analysed in this study include:

- Small biomass
- Heat pumps
- Solar thermal
- District heating
- Low-energy/passive house, building refurbishment
- Behaviour change campaigns/heating control systems/smart meters

For each niche innovation, the following section provides an assessment along the lines below:

- Background (if necessary)
- Description of the niche and characteristics
- Niche actors, social networks, strategies/actions
- Institutions/governance in the niche area
- Summary including an assessment of the niche momentum
3 Analysis of identified niche technologies in Germany

3.1 Small-scale residential biomass heating systems

3.1.1 The particular innovation

Small-scale combustion of solid biomass has in former times been the dominant way for residential space heating and domestic hot water production. Today, it again holds a relevant market share in Germany and is intended to be scaled up for taking a major role in a renewable energy heating strategy.

Within the EU-UltraLowDust project (http://www.ultralowdust.eu) a comprehensive market study regarding small-scale biomass combustion was performed. The shares of the different heating systems show a heterogeneous residential heating stock in Germany: natural gas is dominating, however, the overall share of biomass heating systems is in the range of 6% (relative to 9% in the EU-average, see Figure 7) and can be seen as an important niche technology.

Figure 7: Shares of residential heating systems in Germany and the EU27 in 2011

Germany

| Fuel          | Share | EU27
|---------------|-------|-------
| Natural gas   | 51%   | 45%   |
| Heating oil   | 34%   | 16%   |
| Electricity   | 2%    | 13%   |
| District heating | 12% | 4%    |
| Coal          | 1%    | 3%    |
| Other         | 2%    | 9%    |
| Solar Heatpump | 2%   | 2%    |


Overall, there are about 14 million biomass space heaters and 0.5 million boilers installed in German households (UBA 2013) that are mostly fired with solid woody biomass. Due to the large number of installed “Small Combustion Installations” (SCI) in private households, residential combustion of biomass solid fuels for space heating and warm water production already holds a considerable share of the total heat supply from biomass and other renewables (Figure 8).
There is also a considerable trend to further increase thermal biomass utilisation (Figure 9). A significant part of the dwellings is already equipped with compatible infrastructure (heating pipes, chimneys etc.) so there are good preconditions to realise further growth. Therefore, in the residential sector, a change is most probable as a replacement for old oil- and coal-fired systems (together currently 35%) and an option for new and refurbished buildings. A further increase of the gross floor area is expected in the future, which also offers a certain growth potential for the number of biomass heating systems. On the other hand, a reduction of the nominal heat load per building is expected due to energy efficiency refurbishment and lower heat demand of new buildings (low energy and passive houses), mainly as a consequence of the EPBD (“Energy Performance of Buildings Directive” 2010/31/EU) and respective national regulations.

It is also an important target to eliminate the disadvantages of SCIs in comparison to oil and gas fired units. Especially the attempt to improve air quality by reducing Particulate Matter (PM) and other health-relevant emissions drives market evolution towards new high efficient and (ultra-) low emission combustion technologies. This development leads to reduced health risks from out-dated products and may initiate several co-benefits with respect to decentralised, sustainable and clean energy supply. Furthermore is could trigger positive economic aspects for the security of supply, the creation of new green jobs and technological leadership. Based on historic market data analysed in the EU-UltraLowDust project, in all scenarios a further increase of small biomass heating is most likely for systems based on wood chips and wood pellets. After 2050, the demand for all types of heating fuels is expected to stabilise or to decrease slightly due to the steady reduction of the specific heat demand of the building stock as general consequence of the EBPD.

Figure 8: Shares of biogenic solid fuels (private households) in Germany

Source: FNR (2014a)
3.1.2 Actors, social network, strategies/actions

The niche actor constellation is somewhat complex: while the German niche is dominated by SMEs highly specialised on biomass combustion technologies, there is also a number of large companies offering a broad portfolio including all types of heating technologies (from biomass to fossil-fuelled, see Table 2). Based on the evaluation of a sample of 1000 heating systems performed by the national market incentive programmes (Marktanreizprogramm, MAP) in 2008\(^1\), an overview of the market structure and relevant actors for pellet-, wood chip- and wood log boilers as well as for pellet stoves is given in Figure 12.\(^2\) The market of small biomass heating systems in Germany is influenced by factors like general fuel price developments and changes in the MAP. For example, the number of installed (mostly MAP-funded) pellet boilers in Germany increased continuously between 2004 and 2013, but slightly faster in time periods with rapid fuel price increases and generally elevated gas and heating oil price levels (Figures 10 and 11).

\(^1\) The analysed sample can be seen as snap-shot, representative for the covered time period and the sector of high efficient and very low-emission MAP supported heaters in Germany

\(^2\) Especially with focus on biomass heating systems with high efficiency and very low emissions, which are the target group of the MAP, Austrian and German products dominate the market. There are also MAP-supported import products from the Czech Republic and Italy, followed by a smaller number of heating products imported from Switzerland and the Nordic countries Denmark, Sweden and Finland (TFZ 2010).
The majority of niche actors develop and produce exclusively biomass niche technologies (Table 2). An analysis of their PR and websites points to clear “green” beliefs and consequent positioning towards markets and policy. Larger producers have biomass products only among others within their product portfolio. Those actors have a more differentiated position as their main business still is with fossil-fuelled products, and do not intend to entirely change the regime.

Within the politically influential Federal Industrial Association of German House, Energy and Environmental Technology (BDH) and the Association of Building, Heating and Kitchen Technology (HKI) who represent several relevant types of heating systems, there is no clear pro-biomass lobby, as fossil-products manufacturers still dominate. A strong niche promotion comes from associations for special biomass fuels, like logwood, wood chips and wood pellets (e.g. Deutscher Energieholz- und Pellet-Verband e.V., DEPV) or the respective combustion technologies, who are in contrast far less politically influential (FNR 2014a, see Figure 13).

Table 2: Actors on the German biomass technology market

<table>
<thead>
<tr>
<th>SMEs (&lt;250 employees)</th>
<th>Actors only producing niche technologies</th>
<th>Actors producing niche and regime technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETA</td>
<td>Paradigma</td>
<td></td>
</tr>
<tr>
<td>Ökofen</td>
<td>Atmos</td>
<td></td>
</tr>
<tr>
<td>Biotech</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guntamatic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KWB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hargassner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lindner &amp; Sommerauer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Künzel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rika</td>
<td></td>
<td></td>
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<tr>
<td>Gerco</td>
<td></td>
<td></td>
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<tr>
<td>Palazzetti</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fröling</td>
<td>Windhager</td>
<td></td>
</tr>
<tr>
<td>Solarfocus</td>
<td>Viessmann</td>
<td></td>
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<tr>
<td>Solvis</td>
<td>Sieger/Junkers</td>
<td></td>
</tr>
<tr>
<td>Heizomat</td>
<td>Buderus</td>
<td></td>
</tr>
<tr>
<td>Wodtke</td>
<td>MCZ</td>
<td></td>
</tr>
<tr>
<td>Calimax/Westfeuer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Number of manufacturers | 19 | 7 |
With regard to the decisive actors, producers and households, part of the niche development depends on external factors such as fuel prices, investment costs, funding, emission limits and the availability of appropriate technologies. Due to decreasing heat demand caused by the trend towards low energy buildings and passive houses, initial investment costs become more relevant relative to the fuel and operation costs. Thus, without advancement, residential bio-
mass heating systems may become less attractive compared to alternative heating systems with lower initial investment costs (e.g. heat pumps or gas boilers).

Therefore, a challenge remains to develop new, innovative and cost effective biomass combustion solutions to provide competitive and environmentally sound products to increase the overall share of small biomass. This becomes even more relevant, as the small and medium enterprises active in the field have to compete with large-scale developers of other heating systems, which are frequently supported by powerful energy companies. This niche configuration strongly limits the overall momentum of the technologies.

Figure 12: Market shares of biomass technology manufacturers within the MAP

Sample: 1000 biomass heaters supported by the German MAP in 2008. Source: TFZ (2010)
3.1.3 Institutions/governance

Besides European directives (Ecodesign and Energy Labelling), there are policy instruments for SCI in Germany with a strong influence on the small biomass niche. These instruments are largely the result of emission reduction policy measures and of the attempts of the German Federal Government to promote energy efficiency and the development of renewable energy sources in the buildings sector.

There are direct funding programmes of the Federal Office of Economics and Export Control (www.bafa.de) as well as adapted loan programmes by the federal Bank for Reconstruction and Development (KfW, www.kfw.de) to support energy efficiency measures and renewable energies in the heating sector. Biomass-based heating systems have also a high relevance in the German energy saving regulation for buildings (EnEV). Due to the very low primary energy factor of 0.2, general building requirements of apartments and buildings concerning the primary energy consumption can be reached cheaper through the installation of a biomass-based heating system.\(^3\) (FNR 2014B).

\(^3\) The primary energy consumption is calculated based on the final energy consumption and the primary energy factor. The factor for gas or oil is for example 1.1.
To address efficiency and emissions of heating appliances directly, new mandatory performance requirements come into effect in the near future (German “First Ordinance on the Implementation of the Federal Immission Control Act”/“1. BImSchV”, 2nd tier coming into effect as of 2015). This amended regulation will have far-reaching effects regarding the implementation of primary and secondary measures for emission reduction purposes as refurbishment or replacement obligations also apply for existing biomass SCI. Consequently, they will foster a much faster market and stock transformation in the small biomass heating sector.

Additional measures are performed to further decrease the overall environmental impact of biomass small combustion. This includes support and guidance to installers and end-users by target group-specific information material, through promotion, networking, education and training programs. All these actions focus on installation- or user-dependent factors, such as quality of installation, fuel quality and user behaviour. They are also intended to influence general buying decisions of consumers towards Best Available Technology (BAT) and to reduce emissions in real-life operations by applying best practice principles.

**3.1.4 Overall assessment of niche**

Small-scale biomass heating technology can at least partly be regarded as compatible to the incumbent regime and some of the involved actors are large established heating appliance producers. State-of-the-art technology (condensing boilers) is being used for biomass heating and change is incremental. No deeper behavioural change or significant sets of new actors will be necessary for a basic transition as existing actors and entrepreneurs actively develop and promote the technology. This niche technology follows pathway A in Germany. The momentum towards a significant increase of the small biomass share is currently limited, mainly as consequence of persisting barriers for faster technology adoption and heterogeneous interests among the actors. The most relevant barriers for consumers are linked to higher initial investment costs and potentially higher maintenance efforts relative to other heating systems. Due to the increased sensibility of the general public regarding environmental impacts of residential heating systems, also considerations related to the possible trade-off between CO2-reduction and air quality aspects can be an issue.

On the other side, very promising biomass boiler and stove technologies with high efficiencies and ultra-low emissions already exist. Thus, these new small biomass technologies have to be further optimised for large-scale production to activate economies of scale and need also the support by appropriate policies and information campaigns. Through this, ultra-low emission small biomass technology in combination with adequate policy packages for SCI can provide a major contribution to achieve the declared German and EU-wide sustainability targets.

Hence, the transition momentum of this niche is rather moderate. It should also be kept in mind that small biomass only supports CO2 reduction targets as long as fuel and equipment fulfill the necessary criteria of sustainability. Chances for further upscaling in Germany depend on the collaboration of the niche actors and whether they overcome conflicts of interest.

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4 Primary measures directly influence the emission formation process and are therefore the preferable option compared to secondary measures (e.g. particle abatement systems)
when producing both biomass and fossil-fuelled installations, as well as governmental activities for changing the regulatory and incentive frameworks.

3.2 District heating

3.2.1 Background and technology description

District heating (DH) has a long history starting with first pilot installations in the 1950s. Since then, the grid has expanded to a total of around 20,000 km in Germany, and hence is among the longest European grids (although not in market share)\(^5\) and remains relatively stable over the last decade (see Figure 14). The cooling grid has a length of 33 km (AGFW 2013), which is marginal and therefore not regarded here. DH has a total heating market share of about 7% (AG Energiebilanzen 2014). With regard to connected households, the share is much higher in the formerly socialist eastern parts (32%) than in the former western part of the country (9%). The DH system has always been largely dominated by fossil fuels in Germany. As Figure 15 shows, this trend has not changed: by 2012, only 3% of the heat load came from biomass and 9% from waste heat, therefore other than in Sweden where a fuel switch to biomass has taken place, district heating cannot be regarded as an entirely “green” niche in Germany.

Figure 14: Installed kilometres of district heating grid in Germany

* only reported data. Source: AGFW (2013)

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\(^5\) This may be compared to the other large district heating network countries Denmark (over 30,000km), Sweden (almost 23,000km), Poland (almost 20,000km).
In 2012, 82% of all district heating plants are combined heat and power plants (CHP) (AGFW 2013). Therefore, in the German case, CHP is mostly equalled with district heating. CHP installations are thermal power plants utilizing both thermal and electric energy from the combustion process. CHP mostly generate steam used for the operation of steam turbines generating electricity. At the same time, surplus heat is used for district heating which increases total efficiency of the plants, typically to about 50-90%. The highest efficiencies of 85-95% are reached by gas-fired CHP (UBA 2014). Most CHP plants are flexible as to the share of energy use for heating/electricity generation (at least to a certain extent). Therefore, albeit not a genuinely “green” niche, district heating contributes at least to a more efficient heating (and electricity) system in Germany.

In a cross-European comparison, Germany holds a top position in DH and CHP generation capacity and production in absolute terms. However, the overall market shares are rather low: in the heating sector 7% in 2013 (AGEB 2014) and in the electricity sector about 10% in 2008 (which is only a mere rank 15 in Europe; Ziesing 2008). By 2012, the share of the electricity sector had increased to 16% (Prognos 2013).

Due to the fossil-fuel dominance, DH energy prices are rising with input fuel prices. As these are mainly gas and coal, price increases are lower than for heating oil but higher than for biomass and about parallel to gas (see Figure 16). This is generally seen as one factor contributing to the stagnating market share of DH.
3.2.2 Actors, social network, strategies/actions

In the DH sector, the main actors are the large incumbent energy providers as well as grid operators. In Germany, most DH plant and grid operators are partially publicly owned and partially private companies. Due to the physical grid infrastructure, the demand side (consumers, in many cases housing enterprises passing the costs to end-users) face a local monopoly, which led the German federal cartel authority to check on the DH market in 2012. The authority found, that in some cases, DH providers used their monopoly power to raise inadequately high fares, asked the respective companies for explanations and will possibly start investigations (Bundeskartellamt 2012). In the DH and CHP technology field, it is hence mainly a few large plant manufacturing companies (such as Siemens) who are driving innovations.

The umbrella association for DH and CHP providers is AGFW, lobbying for better DH framework conditions, norms, and providing information on DH. The association of the German energy and water companies (BDEW) is the main actor lobbying for better legal framework conditions for CHP.

NGO actors such as the Association for environment and nature conservation (BUND) are as well lobbying for the extended use of CHP (in combination with DH)\(^6\) in Germany (BUND 2013). However, German NGOs opposed the privatisations of the 1990s and 2000s and want

\(^6\) The CHP could also be applied in industry, using the heat for manufacturing processes.
plants and grids back in public ownership. This makes a streamlined position of the various niche actors difficult, given that large private companies currently own a significant share of plants and grids. The niche’s state is further complicated by its direct link to the Energiewende with high uncertainties for investors and a history of failed investments especially in gas power plants over the last years and a non-existent bust cost-intensive infrastructure.

Figure 17: Actors of district heating niche

### 3.2.3 Institutions/governance

There is no consistent strategy to fully switch to a DH heating system even in regions where this is technically and economically sound such as in densely populated urban areas, compared to the past developments e.g. in Sweden, where such a transition has taken place.

Still, in the German energy transition (“Energiewende”) framework, CHP (in combination with DH) plays a major role: The overall German target is to generate 25% of the electricity from CHP by 2020 and studies expect that this target may be met (Prognos 2013). In addition to the main Energiewende-law, the renewable energy law (EEG) regulating feed-in tariffs for renewable energies, there is a separate CHP law (KWK-Gesetz) regulating feed-in tariffs for electricity generated from CHP installations and introducing financial support for grids with a tube diameter of 100 mm addressing the need for district heating (and cooling) (BDEW 2014).

### 3.2.4 Overall assessment of niche
In Germany, almost 90% of district heat is generated from fossil fuels (to about equal shares from gas and carbon, see above). This constitutes a major distinction to e.g. the Swedish case, where a full fuel switch from fossil to renewable fuels has already taken place. There may be some potential to a similar fuel switch in Germany, but as a) heat amounts are much larger and b) renewable fuel supply is much more limited, a full “green” transition cannot be expected. Although AGFW (2013) sees a grid extension potential of about 100% in Germany, it may be doubted that these figures are realistic given the stagnation of the last decade.

German district heat mostly comes from CHP plants (82%, AGFW 2013), the development and assessment of both technologies are thus closely connected. There is a large variance in CHP efficiency (depending mainly on the age and type of installations). The deployment of CHP depends highly on seasons (due to heat demand) and electricity prices. When heating demand is low (summer), electricity wholesale prices are low (e.g. in the summer due to high photovoltaic electricity generation), gas prices are high and ETS certificate prices are low (making electricity generation from coal relatively cheaper), the operation of the most efficient gas-fired CHP is uneconomic and respective CHP plants will not be deployed. Therefore, for a significant further take-off of high-efficiency CHP technologies (and district heat use in winter seasons) in Germany, these influencing factors are both difficult and decisive.

Environmental NGOs are very critical on carbon-fuelled plants, which represent about 42% of district heating plants. Another point they raise is the reverse of the privatisations (re-communalization) of the 1990s. So that support from this side for a large-scale instalment is limited at best.

If the framework conditions (carbon prices, grid regulations, others) change in favour of gas-fired CHP plants, the technology may gain further momentum in Germany. Higher prices of EU carbon emission certificates would e.g. increase the relative competitiveness of CHP plants and thus make CHP-connected district heating more attractive to operators. This depends largely on policy initiatives at the EU level. More favourable grid regulations depend on a future review of the CHP law in 2014 (Prognos 2013). Increasing the share of renewable fuels in district heating (as happened in Sweden) remains an issue for the political agenda that has not been initiated in Germany and is not in sight. Currently, the momentum thus rather depends on landscape developments such as relative energy carrier price developments.

Assessment of district heating with regard to pathway A or B is ambiguous. While its market entrance in Germany has been a decades-lasting process involving a multidimensional change of the technology base, markets, organisations and policy (pointing towards pathway B), it has not involved social, cultural or practice changes. Main actors have always been large incumbent market actors and although multiple new technologies had to be implemented simultaneously, they fitted well into the existing system. This rather points towards pathway A, and to a preservation of the existing system (Pathway 0).

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7 No information on such district heating fuel switch processes in Germany has been found.
3.3 Heat pumps

3.3.1 Technology description

Heat pumps are used for heating and cooling or to heat water and consist of three main components: 1) Heat energy provision, 2) the actual heat pump, and 3) heat distribution and heat storage. They provide heat by using heat energy from sources such as water, air or soil. Depending on the heat source and transmission different types of pumps exist: water/water, brine/water, air/water, and air/air heat pumps. Hybrid heat pumps use several heat sources.

Heat pump technologies may also be characterised according to the heat generation process (compression, absorption), or the type of heat use (cooling, freezing, water heating). The heat pump compresses the heat transmission agent in a process driven by electric energy to make it hotter on the side to be warmed, and releases the pressure at the side where heat is absorbed.

The heat pump refrigerant (usually fluorocarbon) circulates in a second cycle. A heat exchanger transfers the energy of the first cycle to the refrigerant, which vaporizes. A compressor compresses the vapour of the refrigerant, and the temperature of the refrigerant increases. Under high pressure, the refrigerant condensates in a second heat exchanger. In this process, heat is released and the liquid refrigerant is transferred back to the first heat absorption exchanger by a restrictor valve, which reduces the pressure of the refrigerant.

In the third part of the process, the storage/distribution medium (usually water or air) transports the heat output from the second heat exchanger to a distribution system like a radiator or storage (e.g. hot water tank).

The efficiency of heat pumps is measured by the “coefficient of performance” (CoP) describing the relation between the delivered heat output and the electricity input. Coefficients of performance can be stated for theoretical/laboratory conditions (CoP) or at different operating conditions over the year (seasonal coefficient of performance, SCoP or Seasonal Performance Factor, SPF). Heat pumps have a SCoP of about 2.5 to 4, which means one unit of electricity is needed to produce 2.5 to 4 units of heat (GBZ 2010). The following table presents SCoPs resulting from field tests of heat pumps in existing and new buildings.

Table 3: Seasonal Coefficients of Performance (SCoPs) by heat pump and building type

<table>
<thead>
<tr>
<th>Heat pump Type</th>
<th>Building stock</th>
<th>New building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brine/water heat pump</td>
<td>3.3</td>
<td>3.8</td>
</tr>
<tr>
<td>Air/water heat pump</td>
<td>2.6</td>
<td>3.0</td>
</tr>
<tr>
<td>Water/water heat pump</td>
<td></td>
<td>3.5</td>
</tr>
</tbody>
</table>

Source: GBZ (2010)

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8 For a good overview on the definition of terms see heatpumps.org.uk (2014).
Although water/water heat pumps have the best theoretical preconditions for the highest efficiency in terms of source medium temperature, Table 3 shows higher efficiencies for brine/water heat pumps, due to the electricity consumption of the well pump for groundwater, which has to be accounted for in CoP calculations. According to the evaluation of the market incentive programme 2011 (BMU 2012a) it was not possible to prove mentionable efficiency increases for installed heat pumps so far (BMU 2012a).

Most heat pump systems include an additional heating appliance because especially during the winter season, the heat from the environment cannot supply the necessary heat loads. Furthermore, the SCoP depends on the temperature gap between the heat source (ambient heat), and the heat distribution system (flow temperature): The lower the gap, the higher the SCoP.

**Primary energy consumption of heat pumps in Germany**

The energy consumption of heat pumps amounts to 2 TWh (BMU 2012) or 7.2 PJ. This consumption is already deducted from the values of primary energy consumption (see Table 4).

**Table 4: Primary energy consumption of heat pumps in Germany**

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total primary energy consumption Germany (PJ)</td>
<td>14,401</td>
<td>14,558</td>
<td>14,217</td>
<td>13,757</td>
</tr>
<tr>
<td>Primary energy consumption (PJ)</td>
<td>5.04</td>
<td>5.87</td>
<td>19.17</td>
<td>24.21</td>
</tr>
<tr>
<td>Share of total primary energy consumption (%)</td>
<td>0.035</td>
<td>0.040</td>
<td>0.135</td>
<td>0.176</td>
</tr>
</tbody>
</table>

Source: AG Energiebilanzen (2014), own calculations.

**Market Development**

The sales of heat pumps depend very much on the framework conditions like the current funding criteria and the electricity prices. The decline in sales in 2010 (BWP 2014, see Figure 18) may be ascribed to a two-month funding stop of the German market incentive programme, and the expiration of funding for heat pumps in new buildings.

**Figure 18: Heat pump sales from 2007-2013**

Source: BWP (2014)

Moreover, CoP requirements were tightened in 2010, to only promote the most efficient heat pumps to assure a net contribution to climate protection. A further amendment of market incentives in March 2011 lead to loosened funding criteria (including minimum CoP requirements) (BMU 2012a) so that sales figures increased since then (despite increasing electricity prices).

**Development of investment costs**

Table 5 shows specific investment costs of heat pumps. The values are the result of evaluations for the market incentive programme of renewable investments, and are not a complete market analysis, which limits validity.
Table 5: Specific investment costs of heat pumps (€/kW)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brine-water</td>
<td>1767</td>
<td>1860</td>
<td>1770</td>
<td>1746</td>
<td>-1,20%</td>
</tr>
<tr>
<td>Air/water</td>
<td>1216</td>
<td>1230</td>
<td>1373</td>
<td>1222</td>
<td>0,50%</td>
</tr>
<tr>
<td>Water/water</td>
<td>-</td>
<td>-</td>
<td>1106</td>
<td>1180</td>
<td>6,70%*</td>
</tr>
</tbody>
</table>

Source: BMU 2012a, BMU 2011

*2010/2011

3.3.2 Actors, social network, strategies/actions

The situation of the German niche for heat pumps is currently framed by a dispute over its efficiency and effectiveness. German heat pump manufacturers are mostly large companies, in many cases multinational corporations. They are carrying out research and innovation activities and form networks at federal and regional level. Branch interests are represented by the federal manufacturers association (Bundesverband Wärmepumpe, BWP), whose members cover all parts of the value chain of heat pumps, i.e. manufacturers, energy providers, craftsmen, architects, energy advisers, wholesalers, and retailers of prefabricated houses.

The energy agencies of the federal states and the German energy agency support the diffusion of heat pumps by public relations. Nevertheless, the installation of heat pumps is discussed controversially in Germany.

The BWP works for improved framework conditions (e.g. better consideration in guidelines/laws, funding through incentive programmes) to promote diffusion of heat pumps. Moreover, the association does multimedia public relations work. They organize national conventions, trade fairs, and trainings for craftsmen. On their website they provide information for building owners e.g. detailed information on experts. In conjunction with the Federal Industry Association German Housing, Energy, and Environmental Technology (BDH) they annually analyse the market for heat pumps, publish sales statistics and forecasts.

Both environmental associations (BUND) and consumer associations, the German Corporation for Solar Energy, engineers, and planners (Ö-quadrate, Schaumburg) criticize the environmental protection effect based on the electricity consumption of heat pumps: “Electric heat pumps thwart the energy transition” (Seifried, Schaumburg 2011). To evaluate the environmental effect, the electricity mix for the operation has to be evaluated. Currently, the German electricity mix still relies heavily on lignite (about 25%), hard coal (about 20%) and nuclear energy (about 15%) (AG Energiebilanzen 2014). This means, heat pumps are not yet a “green niche innovation” per se but can have significant (indirect) environmental impacts with regard to energy supply. A more precise analysis would even need to based on the power plants in use during winter time when heat pumps mainly operate instead of on the average. This will change, however, with increasing renewable electricity shares with the German energiewende.

The BUND (2008) for example termed heat pumps sarcastically as “coal heating”: while a heat pump may have a SCoP of 3, if the electricity needed for operation is generated by a low-efficiency lignite power plant, the “real” SCoP may actually be around 1 – with environmen-
tal effects similar to standard lignite room heating. A further argument for lower actual efficiency is that the term CoP is used interchangeably with SCoP due to inconsistent definitions in international literature.

In addition, environmental actors have criticised, that many heat pumps are used as well for cooling with two effects: 1) energy demand for additional cooling appliances increases and 2) refrigerant CFCs typically used have a high greenhouse gas potential.

In consequence, environmental NGOs criticise the coalition of large electricity providers (operating coal and nuclear power plants) and heat pump manufacturers: in their view, heat pumps serve especially for generating additional (and mostly non-renewable) electricity demand (BUND 2008).

Figure 19: Actors of heat pump niche

3.3.3 Institutions/governance

Governance efforts aim to counter the problems mentioned above: Since 2008 the market incentive programme (Marktanreizprogramm, MAP), based on the German renewable energy law (EEG) offers attractive subsidies for the installation of heat pumps in buildings (exception: heat pumps providing process heat), to private persons, small and medium businesses, and municipalities. As precondition for funding, a heat pump needs to comply with minimum SCoPs specified for each type of heat pump. Furthermore, the level of funding depends on the performance of the heat pump. The programme offers bonuses for the combination of a heat pump with a newly built storage system of a certain performance level or with an eligible so-
lar thermal collector and if the building fulfils certain efficiency standards. These bonuses hence cater for an improvement in heat pump efficiency and electricity provision for heat pumps so as to counter the caveats identified above.

3.3.4 Overall assessment of niche

Already today heat pumps have a strong market potential: about 24% of new buildings are equipped with this heating technology (Verivox 2010). Strong lobbying of large energy companies and regional distributors have strengthened the continuous sales. However, significant increases in terms of efficiency cannot be expected at this moment and investment costs have not decreased significantly over the last years (with the exception of brine/water heat pumps that show slight price decreases).

The overall technology assessment depends on the electricity mix used for the operation of heat pumps. Considering the current electricity production structure in Germany, heat pumps cannot be regarded as an environmentally friendly heating technology, as emissions and nuclear waste resulting from the electricity generation needed for their operations are significant. This may change in the future, when the transition of the electricity system to renewable energy is more advanced.

The heat pump market has been steadily increasing to around 60,000 newly installed pumps in 2013. Especially for new buildings, heat pumps already hold a significant market share. The momentum of this niche technology can thus be regarded as medium to high.

As the installations of heat pumps represents only the additional installation of one technical component to an existing heating system, but institutions and socio-cultural practices remain stable and technological progress is incremental, heat pumps can be categorised as pathway A.

3.4 Solar thermal installations

3.4.1 Description of technology

Solar thermal installations convert solar energy into usable thermal energy for heating, conditioning of warm water, or a combination of both systems. Furthermore, there are solar collectors which prepare process heat or cooling. This study focuses on solar collectors for roofs and facades. The two most important technologies are flat plate collectors and evacuated tube collectors. Flat plate collectors, which represent the cheaper alternative, are usually used in domestic applications. As the collectors are not evacuated, a higher amount of the solar energy captured gets lost to the ambient. Evacuated tube collectors are often used to combine conditioning of warm water and heating.

It is important to consider that the appliances typically cover only about 30% of the required heat demand. Therefore, in typical applications they have to be combined with other heat provision systems (such as wood pellet or gas heaters) (Knaack 2014).
Contribution to Primary Energy Consumption

Table 6 shows the development of solar thermal contribution to the total primary energy consumption in Germany between 2000 and 2012.

Table 6: Primary energy consumption of solar thermal installations

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total primary energy consumption Germany (PJ)</td>
<td>14,401</td>
<td>14,558</td>
<td>14,217</td>
<td>13,757</td>
</tr>
<tr>
<td>Solar thermal primary energy consumption (PJ)</td>
<td>4</td>
<td>10</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>Share of total primary energy consumption (%)</td>
<td>0.026</td>
<td>0.070</td>
<td>0.132</td>
<td>0.160</td>
</tr>
</tbody>
</table>

Source: AG Energiebilanzen 2013, own calculations

The primary energy consumption from solar thermal increased about 5-fold from 2000 to 2012, with the share in total primary energy consumption increasing from a marginal 0.026% to 0.016%. Looking at only the primary energy demand of heating in German households, the share of solar heat is still smaller than 1% (BSW Solar 2014).

Market Development

The market development of solar thermal collectors in Germany is unsteady. In 2008 the installed collector surface peaked at a newly installed collector area of 2.1 million m² – this could be due to high prices of oil. Since 2009, the newly installed collector surface decreases due to the financial crisis and decreasing oil prices (BSW 2012), with a slight recovery in 2011 because of higher prices for fossil fuels, especially oil (c.f. Figure 20).

Figure 20: Installed collector surfaces (in 1000 m²)

Source: Own graph based on BSW Solar 2014

In the following years, the annual installed collector surface decreased further (BMU 2012a). The evaluation of the market incentive programme of 2011 (BMU 2012a) concludes that investment incentives from manufacturers, sales and subsidies policy regarding solar thermal are not attractive enough to reach formerly high sales figures.

Furthermore, the demand of solar thermal systems for multi-family houses and innovative implementations like cooling and industrial process heat is still very low. In addition, photo-
voltaic installations are directly competing with solar thermal systems regarding the available roof areas and the general conditions. Even without the German renewable energy feed-in-tariffs (EEG), competition between photovoltaic and solar thermal installations is high due to heavily declining prices of photovoltaic installations.

**Development of investment costs and efficiency**

To evaluate the sectoral cost development of solar thermal systems, we consulted the evaluations of the market incentive programme (Marktanreizprogramm, MAP) since 2004. Unexpectedly, the costs per m² of collector surface area increased for several collector types (c.f. Figure 21). Between 2004 and 2005, the costs increased by 1,7% to 737 €/m². For system expansions investors had to pay 4,2% more, meaning 492 €/m² (BMU 2006). This development also continues in the following year and is outlined in the Table 7.

**Table 7: Development of specific investment costs by collector types (in €/m²)**

<table>
<thead>
<tr>
<th>Collector type</th>
<th>2006</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Space Heating</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat plate collector</td>
<td>681</td>
<td>718</td>
<td>762</td>
<td>778</td>
</tr>
<tr>
<td>Evacuated tube collector</td>
<td>1,053</td>
<td>1,145</td>
<td>1,003</td>
<td>1,052</td>
</tr>
<tr>
<td><strong>Water Heating</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat plate collector</td>
<td>736</td>
<td>889</td>
<td>903</td>
<td>-</td>
</tr>
<tr>
<td>Evacuated tube collector</td>
<td>1,141</td>
<td>1,196</td>
<td>1,351</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: BMU 2012a, BMU 2007

The increasing costs result from rising commodity costs. Especially the prices for copper, which is used for absorber material in solar thermal collectors, have increased heavily. On the other hand, collector efficiency has continuously increased, too: The Federal Ministry for Environment estimated annual efficiency improvements of 0,5% between 1994 and 2003 (BMU 2012a, BMU 2007).
Today, the efficiency of solar thermal systems has almost reached its technical maximum (BSW Solar 2012).

3.4.2 Actors, social network, strategies/actions

The Federal Association of German House-, Energy-, and Environmental Technology (Bundesindustrieverband Deutschland Haus-, Energie- und Umwelttechnik e.V. - BDH), encompassing several different big industrial heating contractors, is very influential. For them, solar thermal installations are just one technology in a broad portfolio among other heating technologies. The association does not only represent branch interests, it also focuses on energy efficiency and renewable energy. This is in line with European and national energy- and environmental policies and furthermore offers benefits for the branch (high job intensity of modernisation projects, energy savings, etc.).

The association that represents the specific interests of German solar firms is the Bundesverband Solarwirtschaft e. V. (BSW Solar). It has been the most influential player in the recent past. Approx. 1,000 firms along the whole supply chain, such as suppliers of raw materials, manufacturers, craftsmen, operating companies and planners are associated with BSW Solar. The association delivers information to the different parties, gives advice, and functions as a mediator between interests of business, politics, and consumers. The BSW aims at influencing political framework conditions for a steady expansion of solar systems (heat and electricity). The target is to integrate solar energy as a main part of the energy industry and to make solar heat and photovoltaic systems profitable. In the past, BSW Solar effected an expansion of the market incentive programme for solar thermal installations and an increase of the funding rates. BSW also lobbied for the renewable heat law, which was released in 2009. BSW also actively and strategically promotes the market for solar thermal installations. On their webpage, they present relevant updates regarding the current frameworks and laws. There are different tools on technical matters regarding solar thermal. An interactive solar-technical advisor helps to find the optimum funding for installing a solar thermal system and a register, which gives the user an overview on craftsmen, registered by postcodes. Especially small and specialized solar manufacturers belonging to BSW Solar are very innovative as they are under pressure in a very competitive market (Knaack 2014).

Otherwise there is a difficult environment for solar thermal installations: There is a direct competition to building energy efficiency measures (such as insulation) as long as the existing heating system still works. Both are rivalling for limited investment funds. For rented buildings, investment costs for insulation (e.g. wall or windows) can be split between tenants and owners, while costs for solar thermal systems cannot. This is seen as a strong barrier for this technology in rented buildings. In addition, as solar thermal only covers a share of the overall building heat demand, it has to be combined with another heating system. Therefore, it as well directly competes with all other heating systems, which are able to supply the entire building heat demand (ibid.).

An example for this are the typical district heat providers using “waste heat” from the combined heat and power process that have so far been rather opposing actors to solar thermal appliances. However, as electricity wholesale prices are decreasing, especially in the summer, the combination of photovoltaic electricity and solar thermal (warm water) may be an interest-
ing solution and some rethinking has started. Denmark may provide interesting best practice cases for solar thermal district heating (ibid).

With respect to the industrial process heat sector, solar thermal is not relevant in the moment. The exemptions from electricity tax, surtax on combined heat and power, and from the EEG feed-in tariffs obstruct the substitution of process heat by solar thermal, especially for larger-scale applications (Fichtner 2013).

Figure 22: Actors of solar thermal installations niche

3.4.3 Policy instruments and funding

The German market incentive programme (Marktanreizprogramm, MAP) is the main instrument of the Federal Government to foster heat production from solar energy. Depending on the type and the size of the installation, basic state funding or additional bonuses are available. For innovative systems, innovation funding is possible. Moreover, the German Bank for Reconstruction and Development (KfW) provides subsidised loans. The criteria and requirements for funding are adjusted in irregular intervals.

In 2009, the renewable energy heat act (EEWärmeG) became effective. This law forces new buildings to produce parts of their heating and cooling demand through the use of renewable energy. When using solar thermal, the share of renewable energy of the entire building energy consumption has to be at 15%.

In addition to the above-mentioned instruments of the Federal Government, there are regional regulations and incentive programmes in the respective federal states of Germany.
3.4.4 Overall assessment of niche

Solar thermal installations can contribute to the transition towards a building stock using renewable energy for heating. However, as this technology only covers a part of the entire building energy demand (at least in the winter season and in existing buildings), it will likely remain as a co-source of heat supply. As only one technical component is added to an existing system, institutions and socio-cultural practices remain stable and technological progress is incremental, solar heat can be categorised as pathway A.

As presently technical efficiency is almost exhausted (with some exceptions in specialised applications) and significant price decreases have not occurred and are not expected in the near future, and as solar thermal installations compete directly with photovoltaics in roof area as well as with other building energy efficiency measures and photovoltaics in terms of investment funds, the outlook is somewhat uncertain.

Technology manufacturers are lobbying for a more supportive policy framework and especially single dwelling house owners are investing in solar thermal technology in spite of relatively high costs. However, the momentum of the further development of this niche into the mainstream system will largely depend on landscape conditions such as energy carrier prices and conditions influenced by the regime such as market incentive programmes or tax exemptions. At current levels, the momentum can be regarded as very limited.

Especially in the industrial sector, there are still technical potentials that could be analysed and potentially lead to a future application field.

3.5 Low-energy/passive houses

3.5.1 Background

For the transformation of building stock towards low-energy housing, there are two main strategies: new construction (e.g. “KfW50” or passive house standard) replacing inefficient stock, and the energy-efficient refurbishment of existing building stock.

In Germany, the majority of residential buildings (75%) has been built before the enactment of the first Thermal Insulation Ordinance (WSchV)\(^9\), an energy performance standard for buildings in 1977 (Schröder et al. 2011; cf. Eicke-Henning 2011). It is estimated that 20 million residential buildings or 50% require substantial retrofits and promote target levels of e.g. 50 kWh/m\(^2\)a (= KfW50 standard) or even <15 kWh/m\(^2\)a (= passive house standard). Given the transformation challenge and the situation of the German market, not only passive houses are considered here, but low-energy housing in general.

Currently, around 140,000 new buildings are being constructed annually (see Fehler! Verweisquelle konnte nicht gefunden werden.), total stock is about 18.4 mn (Destatis 2010), yielding a replacement rate of 0.7%. With a yearly construction of about 500 passive houses, Germany is leading in this niche technology, but its market share in new constructions is only 0.4% (authorized constructions 2011). Calculating the replacement rate for apartments from

\(^9\) Exact wording is: *Verordnung über energiesparenden Wärmeschutz bei Gebäuden* commonly known as *Wärmeschutzverordnung* (WSchV).
Table 9 yields 0.3% (2012). Of these newly built apartments, about half have been financially supported by the public development bank KfW to reach high energy-efficiency standards. The total number of passive houses in Germany is not exactly known, figures oscillate between 10,000 and 15,000\(^\text{10}\), about 0.05-0.08% of the building stock, while the number of households living in these dwellings is not known.

Refurbishment rates are only slightly higher: refurbishments supported by KfW for high energy-efficiency amounted to 0.6% of the apartment stock. In 2012, 88,000 applications for 242,000 building units were approved (c.f. IWU 2013) At these stock transformation rates, the low-energy transition will take over 100 years.

Table 8: New residential construction authorizations (and termination of passive houses)

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
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<tbody>
<tr>
<td>total new constructions</td>
<td>119,026</td>
<td>125,661</td>
<td>144,797</td>
<td>139,492</td>
<td>141,902</td>
</tr>
<tr>
<td>residential passive houses authorized</td>
<td>493</td>
<td>570</td>
<td>(376)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-residential passive houses authorized</td>
<td>24</td>
<td>42</td>
<td>(31)</td>
<td></td>
<td></td>
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</tbody>
</table>

Source: Destatis (2013b)

Table 9: Apartments (new, new with EE-incentives, refurbishment with EE-incentives) in 1000

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
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</thead>
<tbody>
<tr>
<td>Apartment stock</td>
<td>40,057</td>
<td>41,223</td>
<td>41,374</td>
<td>41,550</td>
<td></td>
</tr>
<tr>
<td>new constructions</td>
<td>157</td>
<td>168</td>
<td>205</td>
<td>217</td>
<td>242</td>
</tr>
<tr>
<td>new (with EE incentives)</td>
<td>81</td>
<td>115</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>refurbishment (with KfW EE-incentives)</td>
<td>181</td>
<td>242</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


3.5.2 Technology description

Building stock in Germany needs technology upgrades including the insulation, window and changed heating system. For arriving at target standards, all measures described have to be realised, but realisation often comes in succession. In order to improve insulation, building owners use mineral wool and expanded polystyrene (EPS) (see Figure 23). Both guarantee

\(^{10}\) Figures do not distinguish single/multi-family dwellings.
low expenses per m² insulation in contrast to other material. In addition, energetic building performance has also been improved by using thicker insulation material (cf. Figure 24).

Figure 23: Thermal insulation material purchased in Germany (sales in million m³).

Note: Mineralwolle = mineral wool, PU = polyurethane, EPS = expanded polystyrene, XPS = extruded polystyrene. Source: FIW 2013, p. 74

Figure 24: Insulation material thickness (mm) for building refurbishment

Source: FIW 2013, p. 186

In the window market, triple glazed windows with heat insulation are considered to be best available technology (BAT). Their market share increased within four years from 2% to 5% in 2014 (VFF & BF 2011 & 2014). However, around 20 million windows installed still have a heat transmission value of 4.7 W/(m²K) – an energy saving potential of over factor 4.

20.5 million heating systems are in use, with gas-based heating as leading technology. Due to large price decreases of condensing systems over the last decades 60% of new installed systems were high-efficiency gas-based condensing systems (Kehler 2014) in 2012, but 20% of
the installed gas- and 28% of oil-based heating systems are out-dated. Consequently, heating system renewal have large savings potentials (Kehler 2014).

3.5.3 Actors, social network, strategies/actions

Due to different technologies and stakeholders involved, this niche involves a wide range of actors:

The central actors are the owner/investors. However, due to financial limitations and perceived missing justification for the more expensive energy-efficient technologies, the current level of investment in low-energy housing is low. Short assessment periods/high discount rates lead to undervaluing of energy savings and consequently limited investments of institutional actors.

The main association of building owners “Haus und Grund” has a negative perception of refurbishments and predicate their cost-effectiveness on the following four conditions: the building needs to be in a bad energetic condition, all measures need to be taken simultaneously, be (partly) funded by KfW and the costs could be shifted adequately to tenants. As this is seldom the case, they lobby for an “adjustment of the energy saving targets” (Haus und Grund 2014).

The association of tenants (Deutscher Mieterbund) lobbied successfully for a so-called “rent-brake” that limits rent increases. As the federal government now plans to allow more cost-shifting of energy efficiency measures to tenants, the association has a critical position fearing rising rents and doubts the cost-effectiveness of refurbishments (Deutscher Mieterbund 2014).

As 57% of German households rent their apartments – representing 72% of the population (Destatis 2013), the importance of the critical position of both associations becomes clear. Investments have to be taken by owners, but mostly tenants gain benefits – this results in the “split incentives dilemma”. Low-energy or passive house investments are thus more likely for owner-inhabited buildings and easier for newly constructed buildings avoiding split incentives.

NGOs like WWF, BUND, NABU or Greenpeace lobby in favour of building refurbishment and high energy efficiency standards. For passive houses, there is a specialised association of planners, manufacturers and service providers Pro Passivhaus e.V supporting their proliferation. It fights for the introduction of an obligatory passive house standard for new buildings and for refurbishments where technically possible and economically justified (www.propassivhaus.de, access 20.10.2014).

The media is another important actor that discusses whole house retrofitting (WHR) highly controversial, blaming it to be uneconomic or hardly offering any cost savings (FIW 2013, p. 211). While the research institute for thermal insulation FIW (2013) acknowledges the positive contribution that media can play in informing building owners to pay special attention to certain aspects of building retrofits, it criticises that several reports are focused on few case

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11 For example, media articles speak of “Dämmwahn” (“insulation madness”; Zeit Online 2012).
studies with limited scientific objectivity. The passive house association presents a long list of facts typically presented in the media which they reveal as “myths” (www.propassivhaus.de, access 20.10.2014).

There is also massive industrial interest in refurbishment and passive houses. Medium and large heating appliance manufactures have teamed up and build alliances for example with energy service providers (e.g. Alliance for Building Energy Efficiency (GEEA) or German energy efficiency business network DENEFF) lobbying for policy adjustments to raise refurbishment rates (BDH 2013; VFF 2013; GDI 2012, DENEFF 2014).

3.5.4 Institutions/governance

To reach the GHG emissions reduction target of 40% by 2020 and of 95% by 2050 compared to 1990 levels (cf. BMUB 2014) the German government aims to reduce heat demand in buildings by 20% in the medium run and achieve an almost climate-neutral building stock by

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12 The negative image conveyed might be one reason why the number of insulated exterior building components decreased from 42.5 million m² to 40.1 million m² between 2011 and 2012 (cf. FIW 2013, p. 212).
Both targets require a successful increase of the retrofitting rate from 1% to 2% (German Government 2010, p. 27). Therefore, WHR and passive houses are of high importance. The building refurbishment strategy is also interwoven with that of the EU, which, for example, requires member states to design and enforce building energy performance standards (cf. Energy Performance of Buildings Directive 2010/31/EU).

To promote energy efficiency, WHR is embedded in a complex regulatory policy framework. According to the Energy Savings Ordinance (EnEV), introduced in 2002, buildings that are subject to major retrofit works must comply with several minimum energy and heating performance standards that have gradually been raised since 1979, when EnEV’s predecessor (the WSchV) became effective (cf. Figure 26 and Table 10). The latest update was made in 2014 (cf. BMVI 2014).

Figure 26: Development of building efficiency and regulations in Germany (kWh/m²a primary energy)

Note: Primary energy consumption for space heating in German 2-family dwellings (kWh/m²a). BAT (light blue curve) and legal minimum performance standards for new buildings (dark blue) and typically implemented standards (red curve). Source: BMVBS 2011

13 The government’s Energy Concept does not mention a baseline year for building sector targets. BMVI (2013) uses 2008 levels for its analysis.

14 Energy efficiency and renewable energy targets were reasserted by the parliamentary decision in 2011 to phase out nuclear energy by 2022, which was made in the aftermath of the Fukushima accident (cf. UBA & KfW 2012, p. 5).
Table 10: Building component U-Values (W/m²K) according to German regulations

<table>
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<tr>
<th></th>
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<tbody>
<tr>
<td>Roof</td>
<td>0.22</td>
<td>0.20</td>
<td>0.20</td>
<td>0.15</td>
</tr>
<tr>
<td>Exterior wall</td>
<td>0.50</td>
<td>0.30</td>
<td>0.28</td>
<td>0.15</td>
</tr>
<tr>
<td>Basement</td>
<td>0.50</td>
<td>0.35</td>
<td>0.35</td>
<td>0.15</td>
</tr>
<tr>
<td>Window</td>
<td>1.8</td>
<td>1.4</td>
<td>1.3</td>
<td>&lt; 0.80</td>
</tr>
</tbody>
</table>

Source: FIW 2013, p. 55

The federal government has guided energy efficient refurbishment and WHR is making strategic use of the Kreditanstalt für Wiederaufbau (KfW), which provides soft loans and grants to building owners for WHR and single measures (e.g. roof insulation) as well as for the construction or purchase of energy-efficient homes or passive houses. While the CO₂ Reduction Programme introduced in 1996 focussed on single refurbishment measures, KfW has gradually altered its support in favour of whole house refurbishment and also funds the construction and purchase of energy efficient or passive houses. However, the schemes still mainly fund single measures. Since the energy-Efficient Refurbishment programme was launched in 2009, about 80% of funding applications came from single measures even though the scheme is performance-based, offering higher financial benefits the lower the primary energy consumption and transmission losses are (Efficiency House (EH) scheme).

In 2000, the German energy agency (DENA) was founded. One of its aims is promoting energy efficiency and thus WHR. DENA initiates demonstration/ best-practise activities, organises awareness campaigns and trains energy experts. (BMWI 2014b).

To raise societal awareness and inform building owners (and tenants) about advantages of building modernisation, incentive programmes, and to simplify the search for building experts publicly funded online tools were initiated (cf. co2online 2014). To serve as a role model for the residential sector, the government also refurbishes state-owned buildings (cf. BBSR 2012), to increase confidence of building sector.

3.5.5 Overall assessment of niche

An ambitious vision guides residential building refurbishment and promotion of low-energy new buildings in Germany. Minimum standards aim at phasing out least efficient buildings while financial incentives incentivise building owners to use best-available technologies. Information schemes and refurbishment activities in public buildings aim at raising awareness and generating private sector confidence.

However, the niche actor configuration remains difficult. Large parts of environmental NGOs support low-energy housing and providers of energy efficiency construction material and installations perceive the German energy efficiency market as attractive (DENEFF 2013, p. 29). Building owner and tenant associations fear rising costs – both sides are therefore highly critical with respect to building renovations.

A solution to this fundamental conflict is not in sight. Although there are several instruments in place fostering low-energy housing, there is no reason to expect substantial growth in the momentum of low-energy or passive houses.
Further factors for a low-energy housing momentum are: KfW programmes still mainly fund single refurbishment measures, and funds are apparently not sufficient (per measure and in total). Additionally, negative publicity (e.g. in the media) is hindering instead of accelerating investment.

All actions taken so far have not raised the refurbishment rate from low levels of about 1% to the 2% necessary for reaching the energy saving targets in the building sector. The niche can thus be classified as having a low momentum, and medium term prospective remains low to medium if the issues identified are not addressed.

Although technologies are on the market for decades now, and current technological development is very low in speed, it involves many dimensions (technical base, markets, organisational, political, social, cultural, and practices) and multiple technological elements (appliances, infrastructures, policies, etc. This niche hence follows pathway B.

### 3.6 Behaviour change campaigns/Smart metering

#### 3.6.1 The particular (technological or social) innovation

A legislative push by the European Union is currently the main driver for the introduction of intelligent metering systems in Europe, and hence Germany. As a consequence, the smart metering landscape is highly dynamic (see Figure 27). Germany is currently ranked among the “market drivers”, countries where there are no legal requirements for a rollout. Some Distribution System Operators (DSOs) or legally responsible metering companies nevertheless go ahead with installing electronic meters either because of internal synergetic effects or because of customer demand.

The German case deviates in an important aspect from the Swedish case where individual metering and billing (i.e. energy billing based on the actual energy consumption of the end-users) are a relatively new phenomenon and is applied to only about 1.2% of the households (see respective niche description). In Germany, annual individual metering and billing is standard practice since the interwar years (1918-1939). There are only very few exceptions to this practice, e.g. in buildings with high occupant fluctuations (e.g. student dorms) or in caring facilities (e.g. for elderly and disabled persons or boarding schools). Some multi-dwelling owners allocate costs to the tenants by floor area instead of actual energy consumption. However, no figures for these cases were available and they are certainly exceptional. The legal framework (Heizkostenverordnung) mandates a consumption-based billing of 50-70% of all costs (allowing for 100%). We thus identify smart metering as the “next generation” of metering and billing and as the niche technology for Germany.

‘Smart metering’ is proposed to be a promising way of developing energy markets and contributing to social, environmental and security-of-supply objectives. It comes with direct (e.g. displays) and indirect (e.g. billings) feedback of information that can be used in modification or control of actions and behaviour. It was demonstrated to be a necessary enabling platform for behaviour change measures. While savings were sometimes small in percentage terms, absolute savings scaled up to national level can be substantial (Darby 2006). However, for Germany a clear distinction on smart metering between energy services (e.g. gas, heating and electricity) does not exist. German legal frameworks apply for smart metering of gas/heating
as well as for electricity. Moreover, metering for gas is legally linked to installations of metering systems for electricity (Energiewirtschaftsgesetz EnWG § 21d,e,f). Therefore a discussion of smart metering of gas (for heating) is inevitably linked to literature and research on smart metering of electricity.

For behavioural change in Germany, research in the Ruhr area by the Wuppertal Institute (Liedtke et al. 2014) indicated, that there is no linear correlation between building cohorts or heating system and indoor temperature. The results point to user practices\(^{15}\) as decisive for energy consumption regarding space heat. Differences of a factor 5-7 are observed in the same kind of house with same heating systems. On-sight measurements showed that shorter airing periods have a significant influence on energy consumption as well as different comfort temperatures and wrong set-ups of heating systems. Network analysis of a small subsample of participants showed that personal relations are most influential when heating practices are concerned. Manufacturers are aware of these issues with respect to addressing end users. However, in Germany, manufacturers mostly do not directly contact their end-users, since handicraft companies and others work as intermediaries. This is a problem when manufacturers try to establish for instance product-service systems that take user practices into consideration (Liedtke et al. 2014) and the intermediaries are not able to communicate these properly. Smart meters and behaviour change are hence directly linked as metering is a precondition for efficient change.

\(^{15}\) It has to be emphasised that an analysis of social practices regarding heat consist of an analysis of meaning (e.g. financial reasoning, comforting), material (the heating system at stake) as well as competences (application and installation of heating system, knowledgeability regarding linkages of airing and heating).
In 2008, the largest roll-out started in Germany encompassed 100,000 smart meters financed by “E-Energy”, a funding programme of the Federal Ministry of Economics and Technology (BMWi). Large players like RWE Power (one of the leaders in power generation in Germany), Siemens (global engineering and technology services company) and Miele (household appliances manufacturer) joined the project consortium. Customers gained access to real time information on electricity, gas, heat and water consumption. The evaluation of the program has not been finished yet. RWE decides on further roll-out programmes based on the project results, while the Federal Ministry of Education and Research already launched a subsequent funding program for smart grids including smart metering starting late 2014. More than 400 companies joined project consortia demonstrating increasing interest of the German industry.

There is a wide range of feedback tools available to energy utilities and customers in Germany however market penetration is still very low. Besides feedback tools that enable customers to regulate their energy consumption, a number of utilities test and operate demand response and direct load control programmes in order to limit the peak load. While these programmes are small-scale research projects, some of them show promising results for energy conservation strategies. The greatest growth over the last years can be observed in the area of displays (Karlin 2014).

For example, the “trio smartbox” display was developed. It not only covers electricity consumption but also gas consumption. EWE carried out a field test with 400 households. In-
creased transparency led to a 10% average reduction in consumption. The disadvantage would appear to be the price (the display costs €79 and costs are €99). Ernst & Young (2013) estimate that the installation and operating costs (another €29) render smart metering unprofitable for private households in Germany to date.

3.6.2 Actors, social network, strategies/actions, including institutions and governance

The present situation of smart-metering in Germany is uncertain and at a crucial point. Despite the market driven approach legislative initiatives have been of decisive impact both in regulation and liberalization. Since new initiatives are on the way and strongly impact on the actors’ behaviour, we have chosen to deviate from the usual case study framework and include institutions and governance into this part of the analysis.

Legal obligations on smart metering have been expanded in recent years, by the German Federal Government with the Energiewirtschaftsgesetz (EnWG): smart meters must be installed for certain customers and in certain buildings, and utilities must offer load-variable or time-of-use tariffs (only if technically possible). However, many utilities have not yet fulfilled their obligations regarding meters and tariffs, and incentives for utilities and customers are small. An estimated 370,000 smart meters have been installed in Germany so far (BNetzA 2013, p. 169) – it is expected that a roll out of 50 million smart meters will be needed for electricity and 14 million for gas until 2029 in order to meet national and European guidelines (Ernst and Young 2013, p. 222). Slow progress can be traced back to following from unclear regulation and disadvantageous cost-benefit ratios for utilities and customers..

There has been strong progress in smart metering R&D. Energy utilities and smart meter manufacturers have been able to gain important insights into technical and economical issues of smart metering, as well as different possibilities of feed-back information for behaviour change. However, a recent cost-benefit-analysis (Ernst & Young 2013) projects no positive economic outcome of an extensive roll-out, which is a drawback for rapid future diffusion. With respect to gas, Ernst & Young (2013) do explicitly not recommend a mandatory obligation for parallel installations of smart gas metering in combination with smart electric metering. However, the authors consider the added value of smart metering when upgraded to smart home solutions. Smart home solutions integrate metering for energy (electricity, gas) as well as smart home applications such as automatic assisting systems, e.g. for elderly people, home security systems, remote controls via online systems and smart phone applications (also called Ambient Assisted Living) (Ernst & Young 2013).

Forthcoming progress for smart metering systems again comes from the governmental side: The upcoming legislative package “Intelligente Netze” (intelligent networks) is to contain essential legal requirements for safe and efficient smart metering (for electricity and gas) in Germany: a) The amended “Messsystemverordnung” (Measurement System Regulation), regulates standards to prevent abuse and manipulation of data and technical guidelines, b) The Privacy Regulation is planned for technical data security, and c) The Rollout-Verordnung (Rollout Regulation) determines the scope and implementation of intelligent measuring systems. This regulation also defines costs, time frame, and funding schemes as well as which customers are to install smart meters besides the ones named in the EnWG (Ener-
giewirtschaftsgesetz), under consideration of a positive cost-benefit analysis of BMWi (BMWi 2013).

In this context and at this point of time, several actors are identified with different positions (besides the activities of RWE and EWE and increasing interests of SMEs mentioned in chapter 3.6.1):

- The federal association BEMD represents the interests of German energy market service providers. The BEMD is lobbying for a rapid completion and introduction of the legislative package and the rollout (BEMD e.V. 2014).
- The association of communal energy enterprises (Verband kommunaler Energieunternehmen, VKU) is concerned about negative economic effects on local energy supply companies. The association demands adjustments in financing models (e.g. costs depending on structural conditions (urban and rural)) (VKU 2013).
- Actors who represent consumer interests and rights are concerned that the BMWi could oblige customers to install smart meters without economic benefits. In their view customers should not be forced to install smart meters (VZBV 2013).
- The Federal Commissioner for Data Protection emphasizes that the privacy of end users must be protected because consumption data could be used to create detailed consumer profiles (BfDI 2012). This demand could considerably delay the introduction process of smart metering.

Figure 28: Actors of smart metering niche
Weindlich et al. (2013) identified cost and data security as the most potent barriers to a government-led rollout in Germany. If the consumers have the freedom of choice, acceptance problems would be reduced. Customer information is hence obligatory. Momentum of this niche technology thus largely depends on whether the currently critical cost-benefit analysis for Germany will change and a large-scale government-led rollout will be opted for in order to surpass the already existing billing and information regulations and practices.

3.6.3 Overall assessment of niche

Behaviour change campaigns with regard to energy and heat control follow a pathway that focuses on long term behavioural and cultural change and foster new social practices of users rather than the sheer diffusion of a ‘smart’ technology, although they may depend on them. In this regard, the niche is supposed to co-diffuse technology (smart metering) and behaviour (energy conservation and demand-side-management/peak load reduction) It can thus be categorised as pathway B.

As of yet, the niche has not gained momentum beyond pilot programmes in Germany. Smart metering will probably gain momentum in the future due to ambitious policies that rely on substantial potential for energy efficiency gains. However, they will only be effective with regard to savings if complementary behaviour is promoted by these technologies.

For the situation presented above, Germany does not seem to take the role of an ambitious driver in favour of smart metering for gas. To the contrary, with recourse to the above categorisation, regulationwise, Germany is lagging behind with respect to smart metering for gas and there is few economic incentive for end-users on a market-based level. This niche has currently low momentum with a medium-momentum outlook.

4 Conclusion: Niche innovations in the German heat domain

4.1 Overall assessment of momentum

A transition of the German heat domain has not happened yet. The assessment of niche technologies in this study has shown that their respective situation varies considerably. Not all technologies (or sub-types of these) can actually be regarded as “green” or environmentally friendly per se. Solar thermal, biomass heating and whole house refurbishments are real “green” niche technologies. The assessment of heat pumps gives an ambiguous picture: only with fully renewable operated electricity, can they be regarded as “renewable heat source”. DH increases the energy efficiency of CHPs, which is an argument in favour of positive environmental effects. But since CHP are mainly powered by fossil fuels, DH is no green technology as such. The energy saving effect of smart metering seems very limited but the technology may be a necessary precondition for implementing future smart grids.

For every single niche, a multitude of actors is relevant. In all cases political influence was shown to be of utter importance. In this decentralized and heterogeneous market for heat technologies with a wide range of different technologies in use – for example when compared to Sweden – the principal actors for each niche are the owners of property where a technology is to be implemented. As this is common to all niches, Figure 29 lists only a selection of the
additional main actors identified in this report and their position relative to the assessed niches.

The slowly starting transition of the German heat domain does not follow a clear or unified pathway so far. While most niche technologies are incremental technologies supplied by incumbent actors and follow pathway A (small biomass, solar thermal and heat pumps), there are some niche technologies that involve a deeper transition and follow pathway B (low-energy housing, smart metering). District heating seems to be in between.

**Figure 29: Short-listed niches and positions of principal actors and involved governance levels**

On the one hand, this simplified overview shows that there is rarely any niche innovation that is being fully supported (+). On the other hand, ambiguous/critical positions (±) or rejections (-) indicate central support problems of niches.

Due to diverse developments and activities in the different niches of the heat domain, no common cross-technological picture representing the momentum of all technologies at once can be drawn. Instead, the a large variety of momentum be observed and expected in Germany for each niche:

- **Biomass:** ready technology with heavy research & innovation activities resulting in further efficiency gains and price decreases. Some large manufacturers with diverse green and fossil-fuel-based technologies reluctant to support a “100% green” strategy. Fairly good framework conditions and rising sales. Currently moderate momentum but with a good potential due to numerous niche innovators.

- **Heat pumps:** Increasing sales (probably due to effective collaboration and lobbying of stakeholders: manufacturers, electricity providers, craftsmen). Criticism of environmental NGOs (fossil fuel-based electricity input): medium-to-high momentum.
- Solar thermal: technological efficiency exhausted based on present technologies, prices stable at relatively high level (and not declining), competition with photovoltaics for roof area and other building efficiency technology for investment costs. Large potential but limited momentum.

- District heating: technology is ready, in place and used in large capacities in some places, but still a large potential in Germany. As German district heat comes mostly from gas- or carbon-fuelled CHP, relative disadvantage to lignite electricity production as current low carbon certificate prices limit CHP momentum. Also not principally CO₂-reducing for the same reason – not a green niche per se. Investment-intensive and fossil-fuelled district heat is additionally seen ambiguous in the framework of the general German energy transition. If the framework conditions change, this technology may gain medium-high momentum.

- Low-energy housing/passive housing: technology is ready, incentive policies in place fostering Best Available Technology (BAT)-diffusion instead of cheap, shallow refurbishment. Building codes mandate high efficiency standards for new buildings. In the new building sector, low-energy housing thus is becoming standard, but especially due to the split-incentive dilemma between the main actors owners and tenants, low-energy refurbishments are lagging behind their potential, and over the last years, refurbishment rates have not risen significantly. If the framework conditions do not change significantly this technology will have medium momentum.

- Smart metering: pilot phase in Germany. Still many market and implementation barriers. Possible uptake through price decreases and regulatory changes following the EED in the coming years. Low momentum with medium prospect.

This evaluation shows that there are many solutions available and ready. Some are gaining momentum, and for many the future depends on further landscape (e.g. energy and resource price developments) and regime-dependent framework conditions (regulations, subsidy/incentive and information programmes) that may change the positions of the niche actors and their innovations. They all compete with a heating regime that is not entirely dominated by one single technology – although gas has a high market share – but is characterized by decentralization and diverse and competing incumbent technologies. An imminent regime change towards one specific mode is hence not to be expected. An imminent regime change towards one specific mode is hence not to be expected. Table 12 summarises the conclusions of the niche-analysis of the German domain, with regard to relative ranking of perceived momentum, main drivers of momentum, and pathway A/B assessment.

Table 11: Relative ranking and main drivers of niche momentum

<table>
<thead>
<tr>
<th>Relative ranking of niche</th>
<th>Momentum</th>
<th>Main drivers of momentum</th>
<th>Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Heat pumps</td>
<td>Medium high</td>
<td>Techno-economic:</td>
<td>A</td>
</tr>
</tbody>
</table>
|                          |           | - Heat pumps have a strong market potential: about 24% of new buildings are equipped with this heating technology. |"
### Task 2.1  Pathways

<table>
<thead>
<tr>
<th>2. Small-scale residential biomass heating systems</th>
<th>Moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Techno-economic:</strong></td>
<td></td>
</tr>
<tr>
<td>- Persisting barriers for faster technology adoption and heterogeneous interests among the actors. Small niche actors concentrate on exclusive biomass niche technologies and promote green beliefs with a clear positioning towards markets and policy, while larger more influential producers have biomass products among others. Their main business is with fossil-fuelled products – they do not intend to change the regime completely. Chances for further upscaling depend on the collaboration of the niche actors and whether they overcome conflicts of interest when producing both biomass and fossil-fuelled installations.</td>
<td></td>
</tr>
<tr>
<td>- New small biomass technologies have to be further optimised for large-scale production to activate economies of scale.</td>
<td></td>
</tr>
<tr>
<td><strong>Socio-cognitive:</strong></td>
<td></td>
</tr>
<tr>
<td>- Most relevant barriers for consumers are linked to higher initial investment costs and potentially higher maintenance efforts.</td>
<td></td>
</tr>
<tr>
<td>- Rising public sensibility regarding environmental impacts of residential heating systems (possible trade-off between CO₂-reduction and air quality aspects).</td>
<td></td>
</tr>
<tr>
<td><strong>Policy/governance:</strong></td>
<td></td>
</tr>
<tr>
<td>- New small biomass technologies need the support by appropriate policies and information campaigns.</td>
<td></td>
</tr>
<tr>
<td>- Upscaling depends on governmental activities for changing the regulatory and incentive frameworks.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. District heating</th>
<th>Momentum depends on landscape and energy price developments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Techno-economic:</strong></td>
<td></td>
</tr>
<tr>
<td>- There is a strong link between CHP and DH in Germany.</td>
<td></td>
</tr>
<tr>
<td>- The niche’s state is complicated by persevering fossil-fuel dominance. It depends on a direct link to the Energiewende to become a green niche per se. High uncertainties for investors and an often non-existent but cost-intensive infrastructure.</td>
<td></td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>A / B</td>
</tr>
</tbody>
</table>
Due to high gas prices and low ETS certificate prices, installing cleaner gas-fired CHP/DH is uneconomical.
- DH energy prices are rising with input fuel prices. This is generally seen as one factor contributing to the stagnating market share of DH.

**Socio-cognitive:**
- Environmental NGOs are very critical on carbon-fuelled plants, which represent almost 90% of district heating plants. Another point they raise is to reverse privatisations of the 1990s. Support from this side for a large-scale installation is limited at best.

**Policy/governance:**
- If the framework conditions (carbon prices, grid regulations, others) change in favour of gas-fired CHP plants, the technology may gain further momentum in Germany. Higher prices of ETS certificates would e.g. increase the relative competitiveness of CHP plants and thus make CHP-connected district heating more attractive to operators. CHP/DH based on renewables would be desirable for a true transition, however a clear trend towards this is not visible at the moment.

<table>
<thead>
<tr>
<th>4. Low-energy/passive houses</th>
<th>Low (medium)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Techno-economic:</strong></td>
<td></td>
</tr>
<tr>
<td>- Germany has one of the highest instalment rates in absolute numbers.</td>
<td></td>
</tr>
<tr>
<td>- Although technologies have been on the market for decades now, and current rate of technological development is very low, it involves many dimensions (technical base, markets, organisational, political, social, cultural, and practices) and multiple technological elements (appliances, infrastructures, policies, etc.)</td>
<td></td>
</tr>
<tr>
<td>- Installation and refurbishment rates are very low compared to opportunities.</td>
<td></td>
</tr>
<tr>
<td><strong>Socio-cognitive:</strong></td>
<td></td>
</tr>
<tr>
<td>- Niche actor configuration remains difficult: 1. Environmental NGOs support low-energy housing building 2. Owner and tenant associations fear rising costs – both sides are therefore highly critical with respect to building renovations.</td>
<td></td>
</tr>
<tr>
<td>- Negative publicity (e.g. in the media) is hindering instead of accelerating investment.</td>
<td></td>
</tr>
<tr>
<td>- The split incentive dilemma between tenants and owner slows refurbishment rates.</td>
<td></td>
</tr>
<tr>
<td><strong>Policy/governance:</strong></td>
<td></td>
</tr>
<tr>
<td>- Minimum standards aim at phasing out least efficient buildings while financial subsidies incentivise building owners to use best-available technologies. Information schemes and refurbishment activities in public buildings aim at raising awareness and generating private sector confidence. Public buildings are usually refurbished or constructed on low-energy/passive house standards to provide positive examples.</td>
<td></td>
</tr>
<tr>
<td>- Although there are several instruments in place fostering low-energy housing, there is no reason to expect substantial</td>
<td></td>
</tr>
</tbody>
</table>
5. Behaviour change campaigns/Smart metering

<table>
<thead>
<tr>
<th>Low (medium momentum outlook)</th>
<th><strong>Techno-economic:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Technically and legislatively metering for gas and electricity is in general directly linked.</td>
</tr>
<tr>
<td></td>
<td>- Individual metering is standard since the interwar years.</td>
</tr>
<tr>
<td></td>
<td>- The niche has not gained momentum beyond pilot programmes in Germany yet.</td>
</tr>
<tr>
<td></td>
<td>- Studies show limited saving potential of smart-metering induced behavioural change due to high instalment costs.</td>
</tr>
</tbody>
</table>

**Socio-cognitive:**

- Cost and data security are identified as the most potent barriers to a larger rollout in Germany. If the consumers have the freedom of choice, acceptance problems would be reduced.

**Policy/governance:**

- Smart metering will probably gain momentum in the future due to ambitious policies that rely on substantial potential for energy efficiency gains. However, they will only be effective with regard to savings if complementary behaviour is promoted by these technologies. 
- Germany does not take a leading role for the technology of smart metering for gas and only provides few economic incentives for end-users on a market-based level.

6. Solar thermal installations

<table>
<thead>
<tr>
<th>Limited</th>
<th><strong>Techno-economic:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Technical efficiency is almost exhausted (with some exceptions in specialised applications) and significant price decreases have not occurred and are not expected in the near future</td>
</tr>
<tr>
<td></td>
<td>- Competition between solar thermal installations and photovoltaic (roof area) and other building efficiency measures in terms of investments and funding.</td>
</tr>
</tbody>
</table>

**Socio-cognitive:**

- As only one technical component is added to an existing system, institutions and socio-cultural practices remain stable and technological progress is incremental. No strong influence here.
- Especially single dwelling house owners are investing in solar thermal technology in spite of relatively high costs.

**Policy/governance:**

- Technology manufacturers are lobbying for a more supportive policy framework.
- Momentum of the further development of this niche into the mainstream system will largely depend on landscape conditions such as energy carrier prices and conditions influenced by the regime such as market incentive programmes or tax exemptions.
- Legislative incentives/obligations for new buildings to produce parts of their heating and cooling demand through the use of renewable energy. When using solar thermal, the share of renewable energy of the entire building energy consumption has to be at 15%. 

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growth in the momentum of low-energy or passive houses.
4.2 Conclusion about transition pathways

The categorization into individual pathways has already been performed within the niche descriptions. Below, these categorizations are repeated to provide a summarizing overview.

- **Biomass**: This niche technology follows pathway A: Small-scale biomass heating technology can at least partly be regarded as compatible to the incumbent regime and some of the involved actors are large established heating appliance producers. For a basic transition no deeper behavioural change or significant sets of new actors will be necessary.

- **Heat pumps**: Heat pumps can be categorised as pathway A because installations of heat pumps represent only an additional installation of one technical component to an existing heating system while institutions and socio-cultural practices remain stable and technological progress is incremental.

- **Solar thermal**: This niche technology can be classified as pathway A because the technology only covers a part of the entire building energy demand (at least in the winter season and in existing buildings). It will likely remain a co-source of heat supply. As only one technical component is added to an existing system, institutions and socio-cultural practices remain stable and technological progress is incremental.

- **District heating**: Evaluation of the niche technology is ambiguous: The market entry of DH has been a decades-lasting process involving multidimensional change of the technology base, markets, organisation and policy with tendencies towards pathways B. Otherwise the process has not involved social, cultural or practice changes and main actors have always been incumbents. Although multiple new technologies had to be implemented simultaneously, they fitted well into the existing system. This rather points towards pathway A, and to a preservation of the existing system (Pathway 0).

- **Low-energy housing/passive housing**: The niche follows pathway B: Although technologies are on the market for decades now, and current technological development is very low in speed, it involves many dimensions (technical base, markets, organisatonal, political, social, cultural, and practices) and multiple technological elements (appliances, infrastructures, policies, etc.).

- **Smart metering**: The niche includes two aspects: behaviour change campaigns and smart metering technology and follows pathway B: Behaviour change campaigns with regard to energy and heat control follow a pathway that focuses on long term behavioural and cultural change and foster new social practices of users rather than the sheer diffusion of a ‘smart’ technology, although they may depend on them. In this regard, the niche is supposed to co-diffuse technology (smart metering) and behaviour (energy conservation and demand-side-management/peak load reduction)

4.3 Final remarks

The analyses of the niches and actors have demonstrated high influence of legislation and public subsidization for the German heating domain. This has also illustrated that, while to some extent all new technologies and niches are subject to public support and regulation, the
same goes for the incumbent technologies, indicating that the German government pursues no clear transition path. This is somewhat contrary to state influence in the “Energiewende”, where the federal government has been – and still is – a (the) principal supporting actor (Lund 2009, Lipp 2007). It is also interesting to see how the heat domain is related to the “Energiewende”. Actions and effects are sometimes complementary e.g. in biomass, smart metering and low-energy housing (most importantly smart housing) and even support each other. Specifically, some heating technologies have been found to only be CO$_2$-effective, when coupled with renewable energies. However, there are also competitive and conflicting relations e.g. for solar thermal. It can even be speculated that the attention given to the “Energiewende” both by legal authorities but also by the general public might hamper a transition in the heat domain which somewhat stands in the shadows of the electricity domain.

The mixture of incumbent and new actors within the German heating domain is also important to regard. Incumbents are active on many of the new markets within the domain, transcending their role as members of the existing regime and niche actors. There is thus no clear-cut picture of supporters and hinderers in this domain, and contradicting interests within certain groups and even companies exist. Therefore, a very differentiated picture needs to be drawn.
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