Innovation diffusion, public policy, and local initiative: The case of wood-fuelled district heating systems in Austria

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Abstract

This paper comprises a three-level study on wood fuel utilisation for district heating in Austria. First, we discuss the framework conditions for the diffusion in Austria of rural biomass district heating (BDH) plants, an energy conversion plant type which constituted a real innovation in the 1980s. Second, we describe the diffusion of BDH systems in the Austrian province of Vorarlberg, where a variety of biomass energy systems have been promoted by capital grants since 1993, as part of a dedicated bioenergy promotion programme. Third, the paper contains a case study of a 2 MW BDH plant put into operation in 2000 in Rankweil, a small market town located in Vorarlberg on the east side of the Rhine Valley. Analysis of the plant history reveals that an oversupply of forest residues, caused by devastating storms and forest diseases, together with the more general need to rejuvenate severely over-aged forest stands, created strong incentives to form local actor networks and initiatives to push for the adoption and diffusion of centralised biomass heating systems in rural areas. In addition, intensive lobbying and strong political and public support were necessary to successfully combat interventions by both the natural gas industry and influential gas-supplied industrial enterprises. Finally, a capital grant of 45% of eligible investment costs as well as careful capacity expansion and other planning significantly improved and safeguarded the economic viability of the plant. These considerations, combined with a dedicated forest-restructuring programme, render the plant one of the most successful integrated forestry and BDH projects in Vorarlberg, and an important model for later adopters. Overall, the analysis sheds some light on the role of public policy, local actors, and economic and other framework conditions on the market diffusion dynamics of BDH in Austria.

Keywords: Socio-economic aspects; Local actors; Biomass district heating

1. Introduction

Austria, a country rich in forestland (47% of the land area, 3.96 million hectares), has a share of biomass use for energy among the highest in Europe (around 11%, after Finland with 17% and Sweden with 14%). By the end of 2003 more than eight hundred biomass district heating (BDH) plants were in operation, with an installed thermal capacity exceeding 1 GWth (Jonas and Haneder, 2004; Sedmidubsky, 2004). Typically, such systems supply renewable heat for the centres of rural towns and villages, where publicly owned buildings (schools, town halls, hospitals, nursing homes etc.) are the main objects connected, followed by private homes and commercial buildings. While both biomass boilers for the combustion of wood residues, and district heating systems in urban areas, were common in Austria, the implementation of BDH systems in rural areas constituted a real innovation. Public promotion policy measures in the form of R&D, capital grants and counselling have played a decisive role in the swift diffusion of BDH systems, as have pioneering local initiatives and targeted training and education programs for planners, installers, and other stakeholders. Over time, as part of a continuing learning process, technical and economic efficiency requirements imposed by the authorities and funding agencies have been tightened. This has induced a trend towards higher heat energy densities (i.e. pipeline length to heat sales ratios),1

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1Some 64% of all BDH plants in Austria built after 1 Jan 1999 had ratios of below 1000 kWh/m, with 38% of these below 500 kWh/m (KKA, 2005).
the realisation of micro-grids connecting only a few locally concentrated objects, and overall improvements in capacity planning and technical design.

The province of Vorarlberg—situated between Lake Constance, the Rhine River, and the Arlberg Mountain—is also quite rich in forests (36% of the land area, 96,000 ha). Based on the 1998 situation, it has been estimated that sustainable forest biomass use for energy purposes could be almost doubled (VWK, 1998). Vorarlberg began promoting various kinds of wood-fired heating systems in 1993. In June 2005, a total of 71 BDH systems were in operation, and several additional plants were either under construction or in the detailed planning phase. Today, the promotion of BDH plants is effected mainly by grants (for pre-feasibility studies, capital investment, and the connection of private homes; cf. Section 3), but also by the maintenance of a focal point and dedicated education and training programs. The promotion is part of a targeted policy programme for the increased use of biomass energy (“Schwerpunktprogramm Biomasse”) and helps to achieve ambitious policy targets contained in the “Energy Concept Vorarlberg 2010” (AVLR, 2001a). So far, the promotion of BDH systems in Vorarlberg has been very effective, if measured by its sustained impact, achievement of policy objectives, and the amount of (gross) investment, value added, employment, and fiscal effects induced since its inception in January 1993 (cf. Section 3).2 More so, it has triggered important learning effects and led to a certain degree of rethinking, including, for example, a critical reflection upon traditional methods of (predominantly decentralised fossil) energy supply at the individual and community levels, and making better use of locally available resources.

The market town of Rankweil, situated on the Austrian (i.e. eastern) side of the Rhine Valley and with a population of around 11,000 inhabitants, has relatively large forest areas owned by a Buergergemeinschaft (Agrargemeinschaft Rankweil–Meiningen). In the 1990s, after much debate and planning concerning future forestry operations, this Buergergemeinschaft announced plans to erect a BDH plant, the seventh BDH plant to be established in Vorarlberg with an installed capacity of more than 1 MWth.

The project initially faced a number of barriers, including fierce opposition from the incumbent natural gas industry (VN, 2000a). Since its inception the plant has served as a model for several similar projects in the region (e.g. in Ludesch and Braz), and has attracted a considerable number of visitors. Furthermore, in 2002 the underlying project concept, “Schutzwaldsanierung—WärmeverSORgung Rankweil ‘Wärme aus dem Wald’”, received the prestigious Energy Globe Austria Award for its integration of renewable energy use and forest restructuring towards sustainability (www.energyglobe.at; Anon., 2002).

The aim of this paper is to provide a three-level analysis (national–regional–local) on the public policies, actor networks and economic and other framework conditions relevant to the diffusion of BDH systems in Austria. This approach conveys a more comprehensive picture of the situation and leads to a better understanding of the linkages between the various drivers and barriers involved in the innovation diffusion process.

The remainder of this paper is organised as follows: Section 2 introduces the framework conditions and market diffusion of BDH systems in Austria. Section 3 provides an overview of the diffusion of such systems in the Land Vorarlberg. Section 4 presents the results of the case study of the BDH plant in Rankweil. Section 5 concludes.

2. Framework conditions, history, and diffusion of BDH in Austria

2.1. General description

BDH plants are fuelled by wood chips from forest residues, industrial wood wastes, or straw (although straw is not very common in Austria). The biomass fuels a boiler, which heats water that is then distributed through a network of insulated pipes, thus enabling the supply of heat energy for public buildings, residential dwellings, and businesses.

The development and installation of BDH systems in rural areas of Austria started in the mid-1980s. At that time the federal provinces (and federal agencies concerned) did not explicitly formulate quantitative targets (e.g. in terms of a certain number of plants to be established, or capacity installed), but nonetheless tried to maintain support for such projects (cf. REACT, 2004). Diffusion patterns among the nine Austrian provinces were very heterogeneous, with Lower Austria, Upper Austria, Salzburg and Styria being somewhat earlier in the innovation process, followed by Burgenland, Carinthia, Tyrol and Vorarlberg (Rakos, 2001). In the capital city of Vienna, which is also a federal province, BDH plants have so far been irrelevant, although currently one large BDH plant with combined heat-and-power-production is under construction (cf. Madlener and Bachhiesl, in press). Fig. 1 provides an overview of the relative diffusion densities of BDH plants across the Austrian provinces as of 2003, measured by

### Footnote continued

2A certain amount of value added, employment and fiscal impacts also arises from the operation of the plants and from fuel supply. For Austrian bioenergy plants these effects have been quantified for the first time in 1993 in Madlener and Koller (2005). Note that many studies only calculate gross effects, i.e. negative effects due to the displacement of (decentralised) heating systems are not quantified. Hence, interpretations of results from such studies should be made with care, since displacement effects can be in the same order of magnitude as the positive effects created.

3The neighbouring community of Meiningen (pop. 2000 approx.) has, for historical reasons, a stake of 2/3 in the Agrargemeinschaft Rankweil–Meiningen. Today, the Buergergemeinschaft has 760 individual members from Rankweil and 180 members from Meiningen. In addition, the community of Rankweil holds 19.25% of the shares, and the community of Meiningen 25%.
different indicators (per community, per 1000 pop., per 1000 km²). As can be seen, among the provinces initially experiencing a slow diffusion of BDH plants, the provinces of Carinthia and Vorarlberg have apparently been rather successful in catching up. Diffusion densities are surprisingly low in Tyrol, which can be explained by the fact that medium- and large-scale biomass heating systems in Tyrol are on average larger than in most other provinces (cf. Furtner and Haneder, 2005), i.e. there seem to be relatively fewer but at the same time larger BDH plants than elsewhere.

2.2. Framework conditions for biomass energy use in Austria

The deployment of BDH plants in Austria is generally seen as the outcome of both local initiatives and public policy (e.g. Rakos, 2001). At the public policy level the main goal was initially to support agriculture and forestry (Lamers, 2005). Most farmers in Austria own forest as well as farmland. BDH plants were seen as an opportunity to offer disadvantaged farmers, and especially those in rural and/or mountainous areas, a chance to create a new source of income. Hence much of the (early) funding granted for BDH development stems from agricultural funding sources. Later, environmental funding sources were added.

At the end-use level the motivations for connection to a BDH system were somewhat different. A survey undertaken by Rakos (1997) among connected end-users showed that: (1) environmental protection, (2) convenience (heating comfort), and (3) sustainable local development (support of local farmers; increase in energy self-sufficiency) were the main motivations for switching to heat supply from a BDH grid.

The adoption and diffusion of BDH systems in Austria started as a bottom-up phenomenon. Typically, pioneering farmers receiving support from a regional development or energy agency initiated and realised the first projects at a time when there were no formal subsidy schemes in place. The self-propagating momentum and great interest generated by these early plants led to the establishment of regular subsidy schemes and formally institutionalised public support units (REACT, 2004).

BDH deployment programs have typically been managed at the level of the federal provinces. Apart from granting stand-alone funds, the federal provinces also provided co-funding to substantial funding by the Federal Ministries of Agriculture and the Environment (cf. Section 2.4; Haas and Kranzl, 2000; REACT, 2004) and the European Commission. In fact, the accession of Austria to the European Union in 1995 enabled access to resources from EU regional development programs, greatly increasing the funds available for BDH plants (cf. Rakos, 2001, p. 12). During the 1980s and 1990s, agricultural cooperatives received capital grants (up to 50% of the total investment cost) and soft loans from the Ministry of Agriculture. In contrast, commercial operators of BDH plants, such as owners of sawmills, could only receive grants up to 30%. In 1997, eligibility, application procedures, and payment modes for capital grants were largely harmonised, and a joint Environmental Promotion Fund (Umweltförderungs fonds), managed by a special purpose bank, was established. This has greatly reduced the complexity and overlap of the promotional schemes,

\[ \text{BDH plants/1000 km}^2 \]

**Fig. 1.** Variation in biomass district heating densities across the Austrian federal provinces, selected criteria, as of December 2003 (ranking from left to right according to the no. of BDH plants installed, shown in brackets). Source: Furtner and Haneder (2005)/Statistik Austria (2005), own illustration.

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4The Environmental Promotion Fund, regulated by the 1993 Environmental Promotion Act (last amended in 2005) aims at a set of environmentally relevant goals and supports a variety of projects, bioenergy projects being only one of them (cf. UmweltförderungsG, 2005; Lamers, 2005).

5Kommunalbank Public Consulting (KPC), formerly known as Kommunalbank Austria AG, located in Vienna.
and in turn increased the efficiency of funding and administration. Furthermore, technical performance guidelines introduced in 2000 as a de facto standard (ÖKL-Merkblatt Nr. 67; cf. ÖKL, 1999), together with seminars on how to achieve the performance levels indicated in the guidelines, have significantly improved the technical efficiency and economic viability of plants (cf. Rakos et al., 2003).

Apart from capital grants and soft loans, the reduced value added tax rate on wood products of 10% (compared to the standard VAT rate of 20%) constitutes a further, indirect subsidy. In addition, R&D funds have played an important role in the swift diffusion of BDH systems in Austria. While most of these R&D funds have been provided for project-type technical research undertaken by small and medium-sized enterprises (50% co-funding), they have also been available for long-term R&D programs, mainly aimed at enhancing combustion technology. Throughout the 1990s, national R&D funding for biomass technology was in the order of €5 million per annum (Rakos, 2001). Finally, since 1978 Austria has been heavily involved in various activities (‘Tasks’) of IEA Bioenergy (www.iea-bioenergy.com), an international research collaboration, and has thus had direct access to targeted and dedicated information networks.

2.3. Main actors

Probably the three most important actors in the local/regional innovation system were: (1) the local promoters of a BDH project; (2) the agent/s acting in each province as a focal point; and (3) the planners and installers. Successful local promoters have been identified as “typically well-respected residents of the village that are personally highly motivated and that manage to create a consensus in the whole village to realise the project” (Rakos, 2001, p. 8). The agent/s at the focal points (typically 1–2 persons in each federal province) acted as counsellors, taking responsibility for a number of important tasks (e.g. commissioning of feasibility studies, providing administrative support to apply for subsidies, advising on how to found a cooperative, drawing up of contracts with heat customers). The agents also maintained contact with boiler manufacturers, administrative bodies granting the subsidies, and mayors, and hence had a very important networking function with this second set of key actors. Project planners and installers were often small enterprises with fairly broad portfolios of project types, and at least initially were lacking experience with (biomass) district heating systems. As a consequence, in the early years many planning and installation mistakes were made, the most common probably being over-dimensioning of the systems, sometimes leading to excessive project costs and poor economic performance.6

2.4. Monitoring and evaluation

Monitoring and evaluation were conducted mainly at the project level. Local focal points conducted thorough evaluations of all project proposals for which subsidy applications were filed, and undertook some (mainly informal) ex-post monitoring of plant performance by maintaining contact with project operators and by requiring certain information (e.g. fuel use and heat production statistics, emission data). Monitoring and evaluation at the programme level only started in the late 1990s, often commissioned on an ad hoc basis only (for selected federal provinces, see e.g. Rakos, 1998a, b, or as part of EU-funded cross-country research, see e.g. Starzer et al., 2000). The establishment of a comprehensive quality management system has been underway in recent years, whose application will become mandatory for obtaining subsidies in the future (REACT, 2004). To date there has been no

(footnote continued)

6 In the EU project BIO-COST (BIO-COST, 2000) the relationship between national biomass policies and investment costs of BDH plants...
systematic, comprehensive and comparative economic evaluation of the BDH promotion, neither on the level of the overall environmental promotion programme, nor on the level of the focal points. This is partly due to the fact that most federal provinces run their own, independent policy programs, and thus have a limited incentive to embark on a large nationwide coordinated evaluation or benchmarking exercise. There might also be fears that revealed inefficiencies could attract negative publicity. At the plant level, a good monitoring and evaluation programme would probably aim at some kind of productivity benchmarking, such as it is currently underway for Austrian biogas plants (Braun et al., 2005), trying to identify the scope for further improvements in plant performance and system design of both new and existing plants. At the level of the promotion programs, it would be useful to undertake some (continuous) ex-post evaluation of the cost-effectiveness of public co-funding by type of technology subsidised. Ideally, this should also take into account secondary benefits and the degree of mitigation of market failures, both over time and in relation to related energy policy programs (e.g. for other renewable energy sources and/or energy efficiency programs). Furthermore, such a monitoring and evaluation scheme would also have to tackle the scope for reducing public funding and, finally, assess the benefits of further harmonising or even merging the existing promotion schemes at the federal and provincial levels.

2.5. Diffusion dynamics and structure

Fig. 2 depicts the diffusion of various kinds of biomass heating systems in Austria for two different size classes. In particular, from 1990 to 2004 between 150 and 350 smaller plants (100 kW–1 MW) (left plot) and between 15 and 55 larger plants (>1 MW) (right plot) were put into operation each year, leading to a total market penetration of 3300 small- and medium-sized plants and 460 larger-scale plants. As can be seen, the cumulative diffusion process has been relatively smooth for both size categories, and so far seems not to show any saturation trends.

![Fig. 2. Number of newly installed biomass heating systems in Austria, by size class, 1990-2004 (upper plot: 100 kW—1 MW; lower plot: >1 MW). Source: Furtner and Haneder (2005), own illustration.](image)
Fig. 3 illustrates the diffusion of BDH systems in Austria over time. By the end of 2003, a total of 843 BDH plants were in operation, with a total installed capacity of slightly more than 1 GWth (Jonas and Haneder, 2004).

Fig. 4 shows the distribution of Austrian BDH plants by size class (size being measured as installed capacity), in terms both of the number of plants installed (left/blue bars) and of installed capacity (right/claret-red bars). It can be seen that while small- and medium-scale plants up to 1 MW of installed capacity clearly dominate the picture in terms of the number of plants installed, large-scale systems dominate in terms of cumulative-installed capacity. In recent years, a certain trend could be observed towards smaller systems. This trend is likely due to the growing popularity of plants, which only supply a limited number of nearby objects, aimed at reducing both specific investment costs and heat losses in the distribution grid, but it remains to be seen whether this trend will be sustained.

3. Diffusion of BDH systems in Vorarlberg

3.1. General description

Vorarlberg (pop. 373,000; land area 2601 km²; capital: Bregenz) is the smallest and most westerly of the nine Austrian federal provinces. It has borders with Germany, Switzerland, and Liechtenstein (Fig. 5). Annual forest growth in Vorarlberg amounts to some 400,000 m³ solid, of which only about two thirds are currently harvested for various purposes. It has been estimated that current use of biomass heat of some 370 GWh could be increased to 650–700 GWh per year, implying an increase in the share of
biomass in total energy consumption (1997: 8.4 TWh) from
4.5% to 8.5% (VKW, 1998). A recent cross-country study
has investigated the theoretical, technical and economic
supply potentials, use and marketing of biomass for energy
in Western Austria (Vorarlberg, Tyrol) and Southern
Germany (Southwest of Bavaria and Southeast of Baden-
Wuerttemberg), covering a total land area of 28,184 km²
(Schindele and Heiss, 2001). A major conclusion from the
study is that resource constraints and topographical
conditions, in particular the surrounding Alpine foothills
and mountain ranges, limit the scope for trade of forest fuel
between these German and Austrian regions.

3.2. Diffusion dynamics and structure

By June 2005 a total of 71 BDH plants were in operation
in Vorarlberg, ranging in installed capacity from 50 kW to
7.5 MW, and consuming around 200,000 m³ (loose) of
wood chips from various sources every year (Madlener and
Koller, 2005).8 One further plant was under construction
and six others were planned, for which capital grants had
been earmarked. The share of wood energy in total space
heating requirements is currently about 15%, and could
probably be increased to around 20% (Gross, 2004).

In 2001 the province of Vorarlberg published a
significant new energy concept ("Energiekonzept Vorarl-
berg 2010"; AVLR, 2001a), intended to increase the use of
renewables, to make increased use of indigenous energy,
and to mitigate CO₂ emissions. The goals include a
reduction in CO₂ emissions achieved through renewable
energy use of 102,000 t per annum by 2010 (40.8% of the
envisioned total reduction in CO₂ emissions, or a −5.3%
reduction in total CO₂ emissions) and a 25% increase in
the use of energy from solid biomass (+115 GWh). By the end of
2004, BDH plants alone had already contributed about
35% to that target (Madlener and Koller, 2005, 2006).

The distribution of BDH plants in Vorarlberg by size
class is depicted in Fig. 6. As can be seen, small plants of
under 200 kW and up to 500 kW of installed capacity
clearly dominate (joint share of 58.8%), followed by plants
of between 501 and 1000 kW (25.0%), 1001 and 2000 kW
(11.8%), and larger than 2 MW (4.4%). Compared to the
situation in Austria as a whole, a much larger proportion
of plant installations are at the lower end of the size
spectrum (probably due to the relatively small areas of the
province and its high share of mountainous terrain), while
the largest contribution in terms of installed capacity can
be found in the medium size range.

Fig. 7 shows the temporal-spatial diffusion of BDH
plants in Vorarlberg over the time period 1993–2004,
depicted as a sequence of three 3-year time steps (i.e. to
1998, 2001, and 2004). As can be seen, even in the early
diffusion phase there were plants of very different sizes in
all parts of the province. We cannot detect any major
bandwagon effects among neighbouring communities as a
consequence of geographical proximity. A possible ex-
planation is that the province is very compact and well
integrated, so that geographical distance is not a significant
factor.

Finally, Fig. 8 depicts the diffusion patterns of BDH
plants in Vorarlberg over time, measured by four different
variables: (1) the number of new plants built and put into
operation; (2) the number of additional objects connected
to a BDH grid; (3) installed new capacity (in MW); and (4)
heat sales (heating season 2003/04; in GWh).9

As can be seen from the top left plot, in recent years
there has been a steadily increasing trend in the number of
new plants put into operation. The 7.5 MW plant installed
in the world-famous tourist resort of Lech am Arlberg
(1444 m a.s.l.) caused a distinct peak in the number of
objects supplied, installed capacity, and heat sales. To date,
this BDH plant is by far the largest in Vorarlberg,
supplying 200 buildings in total.

3.3. Description and impact of the Vorarlberg biomass
promotion scheme

In Vorarlberg, a capital grant scheme for various kinds
of biomass systems was introduced in 1993 and has since
been modified and refined several times (see Haas and
Kranzl, 2000; and Madlener and Koller, 2005; for useful
overviews). Since its inception a total of 71 district heating

A selection of plants has recently been portrayed with pictures and key
data in AVLR (2004a), and nine of the earliest BDH plants have been
assessed in detail from an engineering perspective (Biegger, 1996).

9Note that in those cases where measurement devices at the end-users’
locations are lacking, the figures provided refer instead to the production
of heat.
systems larger than 50 kW of installed capacity (as of Jun 2005) and 3796 small-scale systems of different kinds (incl. connections to BDH grids; as of Dec 2004) have received subsidies of €24.1 million and €6.4 million, respectively. Of the €24.1 million, a total of €12.7 million has been granted by federal and EU sources, the remaining €11.4 million by the Land Vorarlberg. The €6.4 million for promoting small-scale systems has been provided by the Land Vorarlberg alone. Until mid-2005, total investments in BDH plants amounted to €58.3 million, and by the end of 2004 more than €37.8 million had been invested in small-scale systems (no exact figure can be provided, since pre-1997 investment figures for subsidised small biomass systems are incomplete). The gross value added from these investments has been estimated at €92.9 million, and the gross employment created at some 1580 years (Madlener and Koller, 2005, 2006).

BDH plants in Vorarlberg are promoted in three ways (cf. Madlener and Koller, 2005, 2006): (1) capital grants for BDH systems with a communal character,10 introduced in 1993 (up to 35% of eligible costs); (2) capital grants of up to 35% for connecting residential homes to the BDH grid, introduced in 1997 (€150 or €300 max., depending on the system replaced;11 AVL, 2004b,c); and (3) grants for pre-feasibility studies, introduced in 2000 (30% of eligible costs or €2200 max.; AVL, 1999). Since 2000, the capital grant mentioned under item (1) can be increased by up to 10% if forest wood chips are used, provided certain conditions are met.12 The increase of the grant is computed at a unit rate of €73 per m³ (loose) of forest residues used per annum (cf. AVL, 2001b,c).

The development of investments in BDH plants in Vorarlberg and related grants are shown in Fig. 9 (note that funds are assigned to the year of the initial start-up of the plants, not the actual timing of the payments). As in Fig. 8, the distinct peak in 1999 was caused mainly by the putting into operation of the 7.5 MW plant in Lech. It can also be seen that capital grants from various sources account for a substantial part of the investment, and that EU funds play a role only in specific cases.

4. Case study Rankweil13

4.1. General description

The BDH plant in Rankweil is 100% owned by the Agrargemeinschaft Rankweil-Meiningen, a community forest operation (statutory corporation) with open membership access, established in 1959. The plant was erected and put into operation in 2000, with an installed thermal capacity of 1.7 MWth and a heat network with a total

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10The minimum heat load must be 150 kW of installed capacity, and heat supply must comprise several external buildings.
11The grants amount to €150 per kW of heat load if the switch is from a central heating system or if a new building is connected, and €300 per kW of heat load if the switch is from a single stove or electric resistance heating system, or any other system without hydronic (i.e. water-based) heat distribution.
12The preconditions are: (1) the use of forest residues over a period of at least ten years (contractually secured); (2) the fuel has to fulfil the Austrian standard ÖNORM M7133 (which requires the use of either wood chips from roundwood and branches from the forest, or landscape conservation woods without further treatment); (3) the minimum share of forest residues in the overall fuel mix must be at least 15%; (4) 50% of the grant is paid after completion of the project and 50% after the elapse of five years, when evidence has been provided that all preconditions have actually been met.
13This case study was started in January 2003 and continued, with some interruptions, until December 2005. Bernhard Nöckl, the manager of the BDH plant in Rankweil, provided most of the information on which this case study has been built. For his time and patience in answering all my questions I owe him my special thanks.
Fig. 7. Spatial diffusion of biomass district heating systems in Vorarlberg, 1993–2004. Sources: Land Vorarlberg (plant data), VoGIS (map of Vorarlberg), own illustration.
pipeline length of 3 km. In 2002, the heat distribution grid was extended by about 1 km, so that several new objects could be connected. In 2005, the plant was extended by the installation of a second biomass boiler (1 MW) and an electric filter to mitigate air pollutant emissions, and by the expansion of the heat network by another 900 m. Heat losses in the distribution grid are around 10%. Peak-load demand and emergency outages are covered by an oil-fired boiler (2.5 MW). Wood sorting, handling and storage of both industrial and energy wood is done on the premises (cf. Fig. 10). In 2001, the plant consumed about 8000 m³ of wood chips and in 2002 about 10,000 m³. Some 80% of the wood chips stemmed from thinning operations, the rest were bark and residues from the sawmill industry.

In 2001, the plant supplied 21 public buildings and 61 commercial enterprises and private households. Since then...
2002

50 mg/Nm³, an electric filter was also installed. In order to keep particle emissions below the legal limit of requiring the installation of a second biomass boiler. In principle, this filter enables the retention of up to 99% of the particle emissions. The fly ash kept back by the filter is collected in a container and disposed of properly. Latest emission measurements undertaken in November 2005 showed that the filter reduces emissions of particulate matter from 67 mg/Nm³ down to 5 mg/Nm³ (Nöckl, 2003b).

4.2. Development of a green innovation

4.2.1. Severely over-aged forest as an engine of innovation

Between 1989 and 1992 there were several severe winter storms, causing significant damage to the forests owned by the Buergergemeinschaft. Between 1990 and 1994, a total of about 70,000 m³ of solid wood, damaged either by the storms or by bark beetle, had to be harvested. Damage covering some 175 ha (area damages) and 100 ha (spot damages) of the total forest area of 1340 ha (BWR, 2000; cf. Section 4.5) made it necessary to take a new inventory and to create a new forest cultivation plan. The permanent inventory taken in 1994 revealed that 70% of the mountainous forest and 20% of the lower range forest was more than 140 years old. Members agreed to a forest-restructuring plan (Waldsanierungsplan), according to which a balanced age structure would be achieved within a time frame of 45–50 years. Among other measures, a mobile cable crane was purchased to enable cost-efficient harvesting and to facilitate the forest rejuvenation process. Since part of the over-aged forest in high altitudes is contaminated with butt rot (fomes annosus), use as wood fuel is the only option. However, storm damage had affected the entire region, leading to an oversupply of low-quality wood and saturation of the wood fuel market, so that 35–40% of the fuelwood harvested could not be sold (Nöckl, 2003b). Several communities in the vicinity of Rankweil own forests in less mountainous areas, and this competitive advantage allowed them to sell their fuelwood at lower prices. Out of this dilemma, and the knowledge that more and more homeowners were giving up the more cumbersome logwood heating systems in favour of automated (and mostly fossil-fuelled) heating, the idea was born to build a centralised district heating plant fuelled with wood chips.

4.2.2. How it all fitted together

Independently of the precarious forest situation with which the Buergergemeinschaft was confronted, the community of Rankweil commissioned a feasibility study in 1996 for a central heating network that would supply the town centre and all community-owned public buildings (BWR, 2000). The relatively high building density in the centre of Rankweil provides favourable conditions for district heating. The Buergergemeinschaft took up this initiative, and made further investigations and preparations for establishing a BDH plant. Eventually, the community council formally decided in favour of connecting all community buildings, thus securing a certain baseload demand for heat.

After determining the route for the main pipelines, individual homeowners had to be convinced to get connected to the district-heating grid. This was done mainly by advertising and lobbying (e.g. in the local media), by numerous personal talks, and by waiving the grid connection fees of around €130/kW of heat load. Overall, these efforts enabled to secure an additional heat load of 5.2 GWh (connection of 42 private buildings). The contracts issued, which have a duration of 15 years (or 10 years in the case of the local community), include a clause stipulating that connected parties are not allowed to install a decentralised heating system based on either

(footnote continued)

required for forest rejuvenation—i.e. for achieving a balanced age structure of the forest—would be some 42 years (Nöckl, 2003b).

Several possible locations for the BDH plant were scrutinised. Calculations showed that a location near the wood storage site (historically an old quarry) was favourable, as this would keep to a minimum wood handling and transport distances. The location of the handling site is reasonably close to the community centre, but at the same time largely spares the village from noise emissions.

This was also done because the natural gas supplier waived the gas connection fee, creating substantial competitive pressure. Connection fees for the BDH grid have been waived since, with the exception of potential connectors who had the opportunity to connect to the grid at some earlier point in time (incentive for early connection).

14Installation of a flue gas filter is required by Austrian law for boiler plants larger than 2 MW of installed capacity (cf. LRV-K, 1997).

15That is an inventory in which fixed measurement points are used for sampling.

16Calculations have shown that, taking into account annual forest growth and an annual harvest of 10,000 m³ of solid wood, the time period...
non-renewable energy or heat pump technology (i.e. solar thermal heating and tiled stoves are allowed, in order not to jeopardise the diffusion of systems promoted by the government of Vorarlberg). A further victory was gained by convincing the government of Vorarlberg to supply their local neuropathic hospital (Landeskrankenhaus Valduina) with heat from the BDH plant during summer.\textsuperscript{19} As well as allowing a better annual capacity utilisation of the plant, this additional summer heat load made the installation of a second boiler dispensable, since it was possible to run the winter boiler at a reduced load in summertime (20\%/400 kW).

The initial planning foresaw the connection of 14 public buildings (2.3 GWh) and 48 private houses (2 GWh), and the supply of the neuropathic hospital with heat energy during summertime (for heating and cooling purposes; contracted sales volume 1 GWh). The community buildings connected comprised a retirement home, the old and the new town halls, community hall, kindergarten, primary school and a school for children with special needs (which together constitute the so-called central school), police station and a commercial property, fire station, musicians’ rehearsal hall, two secondary schools, two social centres, a youth centre, and a maintenance depot/operating centre (cf. BWR, \textit{2000}). In 2002, an additional ten buildings with a total heat load of 600,000 kWh were connected.

4.2.3. Important actors

The forester Bernhard Nöckl played a particularly important role, as change agent and opinion leader. He took up his position with the Buergergemeinschaft in 1989, when forest operations were based on an outdated silvicultural plan and organisational structure and were essentially carried out by two employees with no machinery. Much of the early pride of the members of the Buergergemeinschaft had vanished in the face of deteriorating economic conditions for forestry operations, and the main source of income for the Buergergemeinschaft was the revenues gained from renting out a quarry. This young forester brought in new ideas and initiatives (e.g. in terms of environmental image considerations (e.g. membership of “Klimabündnis Österreich”, cf. \url{www.klimabuendnis.at}; participation in the Local Agenda 21 process, cf. \url{www.nachhaltigkeit.at/LA_21.php3}). The project was under attack from powerful industrialists, members of the board of director of the regional natural gas supplier, an argument leader from the local community. At the general assembly meeting of the Buergergemeinschaft in early 1999, where the decision was taken to realise the project, the director—both a member of the Buergergemeinschaft and a businessman with vested interests—argued vigourously that they must be forward-looking.

This seems to have had a significant impact on the outcome of the voting (Nöckl, \textit{2005b}).

Finally, as far as we are aware, the project has received favourable treatment throughout by the print media, and especially by one journalist who reported frequently on the progress of the plant and the challenges faced (cf. VN, 1999a, b, c; VN, 2000a, b; Neue, 2002; VN, 2005).

During the initial planning process, planners and installers were important actors. As mentioned in Section 4.3 below, one planner doing a pre-feasibility study almost brought the project to a halt. Early installers apparently charged excessively high prices for their services, possibly as a risk premium because they were unfamiliar with the technology involved, but perhaps also due to rent-seeking behaviour.

4.3. Business economics

In 1997 a first feasibility study, carried out by a Swiss planner and costing more than €30,000, concluded that the biomass plant was not economically feasible.\textsuperscript{20} Despite this frustrating result, the initiators of the project did not give up. In 1998, a project group was founded, comprising four members of the Buergergemeinschaft and one representative from the local community. The group held approximately 20 meetings over a period of 3 months, and dealt mainly with biomass resource and financial aspects of the project. Ultimately, however, the members of the study group wanted freedom from any responsibility for ill-fated decisions. As a consequence, the project group was dissolved and the mandate given to a new planner, who eventually produced a more favourable feasibility study.

In January 1999 the community council, in which the Buerger had a prominent share of 20\%, unanimously voted in favour of connecting all community buildings to the BDH system. This decision was also influenced by environmental image considerations (e.g. membership of “Klimabündnis Österreich”, cf. \url{www.klimabuendnis.at}; participation in the Local Agenda 21 process, cf. \url{www.nachhaltigkeit.at/LA_21.php3}). The project was under attack from powerful industrialists, members of the board of directory of the regional natural gas supplier, an important incumbent. Eventually, after some rows, construction of the plant started in March 2000, to be successfully completed by October 2000 (cf. the chronology of events provided in Box 1).

The total investment cost for construction phase 1 (1999–2000) amounted to €2.36 million, about 10\% (€218,000) of which was contributed by the community.

\textsuperscript{19}The contractual obligation foresees the delivery of 1 GWh of heat per annum over the period 15 May–15 September. If demand for heat energy falls short of the contracted amount, then the price per MWh of heat delivered (currently 3.05 ct/kWh) increases inversely proportional to the under-consumption, thus safeguarding a certain minimum revenue. Heat sales to the hospital are subject to the same price indexation as are sales to other heat consumers.

\textsuperscript{20}In fact this pre-feasibility study would have cost much more, but the Buergergemeinschaft took the issue to court and won the case. The outcome of the study constituted a severe setback for the further development of the project, since it raised many doubts amongst the members of the Buergergemeinschaft (Nöckl, 2005b).
of Rankweil, conditional on a service obligation concerning the laying of the pipes. Capital grants of 45% of the eligible investment costs were paid by the Land Vorarlberg, federal ministries and the local community, while the remainder had to be borne by the Buergergemeinschaft itself (by a paid-in capital stock, ownership of the wood chips storage bunker, purchase of a caterpillar for the wood fuel handling, and an internal loan granted to the plant operating company, BWR). BWR, the “Biomasse Wärmeversorgung Rankweil GmbH”, was founded by the Buergergemeinschaft as a 100% affiliate, in order to clearly unbundle the costs.

It was expected that at prevailing fuel and heat prices the project would become profitable after 20 years. It was reckoned that break even of the project could be achieved at an average wood chips price of €8.57 per m³ loose and a heat price of 4.8 ct/kWh (cf. Fig. 11 for the development of the actual tariffs charged in recent years). The wood chips price could be kept reasonably low by using a certain share of sawmill residues (bark, sawdust) available at low cost. Currently, the settlement price of forest wood chips is €12 per m³ (loose) or €32 per m³ (solid). The heat price is

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21Interestingly, this capital grant from the community was tied to an obligation to allow for the co-laying of ICT cables in the ground when the heat pipelines were dug in, thus exploiting synergies.

22Another interesting motivation for this step was that if a company like BWR is operated predominantly by farmers, some additional grants can be obtained from the Federal Ministry of Agriculture. The wood chips storage hall and the caterpillar were financed by the Buergergemeinschaft for tax reasons, as a result of which BWR receives the wood chips ‘poured’ (into the feeder) cf. Nöckl (2003a, 2005b).

23Note that due to an ongoing market concentration process more and more sawmills are closing down in Vorarlberg, and of the nine sawmills that once existed in Rankweil not a single one is left today.

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Box 1
Summary of the project history of the 2 MW biomass district heating plant in Rankweil

<table>
<thead>
<tr>
<th>Year</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990–94:</td>
<td>70,000 solid m³ of storm wood</td>
</tr>
<tr>
<td>1996–97:</td>
<td>Revision of the forestry plan</td>
</tr>
<tr>
<td>Nov. 1996:</td>
<td>1st discussion evening about district heating plant; site visit</td>
</tr>
<tr>
<td>Oct. 1997:</td>
<td>Presentation of basic concept</td>
</tr>
<tr>
<td>Nov. 1997:</td>
<td>Local community shows interest in connecting its public buildings to the DH grid</td>
</tr>
<tr>
<td>Dec. 1997:</td>
<td>New forestry plan reveals that 70% of mountain forest stand is older than 140 years</td>
</tr>
<tr>
<td>Jan. 1998:</td>
<td>Project study group established (five members)</td>
</tr>
<tr>
<td>Nov. 1998:</td>
<td>“Heat from the Forest” brochure issued</td>
</tr>
<tr>
<td>Jan. 1999:</td>
<td>Green light from local community council (unanimous vote in favour of connecting all public buildings to the district heating network)</td>
</tr>
<tr>
<td>Jan.–Feb. 1999:</td>
<td>Green light from the general assembly of the Buergergemeinschaft</td>
</tr>
<tr>
<td>Mar. 1999:</td>
<td>Provincial government supports DH supply of local neuropathic hospital (owned by the Land Vorarlberg)</td>
</tr>
<tr>
<td>Jun. 1999:</td>
<td>New location studied, green light from local government</td>
</tr>
<tr>
<td>Jul.–Aug. 1999:</td>
<td>Installation of first heat pipes</td>
</tr>
<tr>
<td>Dec. 1999:</td>
<td>Foundation of operating company (BWR)</td>
</tr>
<tr>
<td>Mar.–Sep. 2000:</td>
<td>Construction (plant, wood chips repository, heat pipes)</td>
</tr>
<tr>
<td>Oct. 2000:</td>
<td>Initial start-up</td>
</tr>
<tr>
<td>2002:</td>
<td>Major grid extension</td>
</tr>
<tr>
<td>2005:</td>
<td>Extension (install. of 2nd biomass boiler and electric filter, grid extension by 900 m)</td>
</tr>
</tbody>
</table>

Source: BWR/B. Nöckl, modified

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Fig. 11. Heat tariffs charged by the Rankweil plant (in nominal terms) for an annual heat consumption of between 1–50,000 kWh, 1999–2005. Source: BWR, B. Nöckl.
linked to a compound price index (1/3 oil price index, 1/3 consumer price index, 1/3 constant price). Hence if the oil price rises, the price of heat from the BDH plant also rises to a certain extent. In contrast, if the oil price index declines more than the consumer price index rises, the price of heat is reduced and consumers are better off. Connected parties are also contractually obliged to pay a monthly base fee of €10.49 excl. VAT (2005 price).

Construction phase 2 (2002) comprised an extension of the plant amounting to €167,400, and phase 3 (2005) a further extension costing €760,000. In both instances the maximum possible grant of 45% of the eligible investment cost was granted by the federal province of Vorarlberg, since the required increase in the amount of forest residues to be used according to the funding directive could be credibly stated in the application.

Box 1 presents a summary of the project history. It provides useful hints on what sequential work steps have been involved in developing the Rankweil BDH plant, and how long certain development steps can take.

4.4. Operational experience

The main problems experienced at the beginning of plant operation were related to some broken gaskets, the control system of the oil-fired peak-load boiler, the optimal injection of phosphate/sulphite as an antioxidant into the pipeline fluid, and a faulty pump. There were no supply interruptions during the first year of operation, apart from the scheduled service outages, and since then there has been only one two-day outage of the biomass boiler that had to be compensated for by the oil boiler. In the first year of operation, the fuel mix was 67% forest residues, 24% bark, and 9% sawdust.

The cable crane (range 800 m) is currently operated on 250–300 days (1500–1600 h) per year. Bottom ash has been certified by an environmental institute as environmentally compatible and is recycled in various ways. Part of it is brought back to the forest,24 part is given away free to livestock farmers for use as an additive to liquid manure fertilizer, and part is used as a fertilizer on ski-pistes (sold at 0.2–0.3 ct€/kg). In addition, a small amount of bottom ash is sold in bags of 15 l to residential end-users at a price of €3 per bag. If the ash from combustion had to be disposed of as waste, it would cost €120 per ton. Fly ash and filter ash contain high concentrations of heavy metal, and therefore have to be disposed of via the appropriate waste channels. Plant maintenance requires, on average, about 1 h of labour per day.

4.5. Sustainable forestry and related considerations

Wood fuel requirements had been calculated at 10,000 m³ loose per year, of which some 60% would come from wood chips and 40% from bark and sawmill residues. The actual amount of wood fuel required (8,000–10,000 m³ loose) corresponds to about 30–40% of the annual forest growth (estimated at 9000 m³ solid p.a., or 24.7 m³ solid per day). In total the forest area is 1340 ha (1520 ha if several alps are included), of which 770 ha is located in a mountainous area, with a wood reservoir of about 500,000 m³ solid (as of 1999). Annual cutting is currently around 11,000 m³ solid, 7000 m³ of which is industrial wood, 3200 m³ fuelwood, and 800 m³ pulpwood. At the time of planning, annual forest growth in the Rankweil forests was slightly less than four times the annual wood chips consumption.

The project is considered sustainable, since even after successful rejuvenation of the forest, there will be a sufficient amount of wood fuel available to operate the BDH plant with own resources. A contributing factor is that forest productivity is increased by the restructuring measures.

The restructuring of the forest is also considered an important measure for erosion, rockfall and avalanche prevention, thus offering certain benefits to the local population and tourists. In addition, 95% of the drinking water of Rankweil is taken from the south side of the Laterns valley (average slope 70%), where large parts of the forest areas of the Buergergemeinschaft are located, constituting a major hydro reservoir of the whole region. A healthy forest has an improved hydrological storage capacity.

4.6. Socio-economics

4.6.1. Value added, employment, and fiscal effects

Performing a static input–output (I/O) analysis based on the Austrian I/O Table 2000 (Statistics Austria, 2004), Madlener and Koller (2005) have empirically estimated that per million Euro invested in the BDH plants built in Vorarlberg, the resulting value added has been €1.1 million and the employment effect 18 person-years. Note that these and the following figures are gross values, i.e. they do not account for the displacement effects caused by crowding out investment into decentralised heating systems, which might be in the order of 20–40%; cf. Madlener and Koller (2006). In the study mentioned the authors also estimated that the fiscal effect due to additional expenditures amounts to some €277,000 per million €. If these empirical results were applied to the Rankweil plant (total investment volume €2.35 million, cf. Section 4.3 above), the resulting value added would be €2.6 million and the employment effect 42 person-years (gross values). In addition to this investment effect, the operation of the plant and the provision of biomass fuel yield additional value added and employment. All figures provided should be interpreted with great caution. Because a national I/O table was used in the underlying study, regional and local heterogeneities are not covered in the analysis (and estimates) and multiplier effects for the region (location)
may be overestimated. Also, if the regional and local economy does not mirror the national economy in sectors and relative size, results can be inaccurate and misleading.

The staff of the Buergergemeinschaft increased from three in 1989 to 22 in 1995, and has since decreased again to around sixteen. However, it is difficult to attribute any number of jobs to the BDH plant, since administration of the plant (own legal entity) is strictly separated from the administration of the Buergergemeinschaft. Moreover, it is difficult to attribute a certain share of labour out of the great variety of forestry-related operations directly to the biomass plant. The reason for the reduction in employment in recent years can be found in a new trend of using external contractors for a variety of tasks. These contractors are typically farmers who do forestry operations as a sideline job, often with shared equipment. Their competitive prices mean that make-or-buy decisions of BWR are often taken in favour of such external contractors.

4.6.2. Social activities

Fig. 12 shows a selection of educational information boards used in the BDH plant in Rankweil for open days and group visits throughout the year. In the initial year of operation alone (2000/2001) around 70 guided tours were organised, about 30% of which were for local visitors (Nöckl, 2003b). The site has been popular for visits among planners of new plants, partly because planners prefer to show a well-functioning plant with a solid financial basis and a proud plant manager, rather than a plant with severe technical problems or running a deficit. Several neighbouring communities have followed the example of Rankweil and built their own BDH plants (e.g. Göfis in 2000; Fraxern in 2003; Sulz in 2004; cf. Fig. 7), although

5. Conclusions

This paper has provided a brief overview of the framework conditions for the diffusion of biomass-fired district heating plants in Austria, with a particular focus on the development and current situation and promotion in the federal province of Vorarlberg. We have also presented a case study of the 2 MW BDH plant in Rankweil, Vorarlberg, which constitutes a good example of the successful adoption of a process innovation in the field of renewable energy use and sustainable forestry.

The investigation at the national level leads to the following conclusions:

- The Austrian experience of a rapid diffusion of BDH plants was the outcome of a combination of high capital grants offered by several funding sources, local initiatives rooted in a mix of environmental concern and self-interest of forest-owning farmers, and the build-up of know-how and networking among the main stakeholders involved.
- Since 1999 the introduction of techno-economic performance guidelines used as a minimum standard for obtaining grants has helped to greatly improve the technical efficiency and economic viability of plants.
- Standardisation and harmonisation of subsidy schemes and application forms, tender procedures, and feasibility studies have been important ingredients for continued quality improvements, as has the establishment of focal points in the provinces providing training, advice and other support services.

From our analysis at the level of the federal province of Vorarlberg we conclude the following:

- Capital grants offered by the Land Vorarlberg and complementary federal and EU sources are substantial, and seem to have played an overarching role in maintaining a sustained diffusion process triggered in 1993. At the same time, education and training programs as well as stiffening technical and techno-economic requirements, have gradually improved the productivity and economic viability of the BDH plants in Vorarlberg.
- Diffusion of BDH plants in Vorarlberg seems to have happened in a geographically dispersed manner, and we could not detect any distinct spatial diffusion pattern.

Note that several smaller-scale BDH plants were built in the local area before the Rankweil plant was realised (e.g. Batschuns (2 plants) in 1994; St. Arbogast in 1994; Zwischenwasser in 1995), but due to their limited size (not directly comparable), special ownership (in three out of four cases the Land Vorarlberg), and dedication (educational centres, home for physically and cognitively challenged children) can be expected to have been less relevant as models. Probably more important and influential in this respect was the plan of the technical director of the neuropathic hospital to erect a biomass heating plant on the hospital premises, which was eventually abandoned once the Buergergemeinschaft had been convinced to build a BDH plant.
Given the compact nature of the province, local proximity seems to be less important than the existence of (sometimes geographically dispersed) innovators/pioneers. This seems to be in line with the idea of epidemic diffusion models such as the one introduced by Bass (1969), which implies that innovators and early adopters apparently get their information from further away than later adopters, which rely more on interpersonal communication.

- The dynamics of diffusion point towards the reaching of the biomass energy policy goals set by the federal province of Vorarlberg in its energy concept 2010, and in recent years indicate a structural shift in favour of larger BDH plants.

At the plant level (case study Rankweil) we conclude the following:

- The Rankweil BDH project was developed mainly due to pressing forestry problems as an important driving force; the preparedness of the community to connect all public buildings and of a large nearby hospital to use biomass heat in summer; and a clear vision and commitment from a few key actors (especially the technical director of the hospital, a local forester, and the managing director of the Energy Institute Vorarlberg).

- The installation of a BDH plant in Rankweil was a precondition of and the central element for launching a forestry project that would enable simultaneously the use of forest residues and the active management of the forest stands towards a more balanced age structure.

- Many of the (early) connectors to the grid were members of the Bürgergemeinschaft, who thus both helped to realise the project, and will, in the longer run, profit from the improved forest maintenance.

- Project realisation was not without problems: it involved a lengthy planning process (incl. a pre-feasibility study with erroneous assumptions/conclusions) and opposition from various stakeholders, especially the natural vested interests.

- Local and regional political commitment in favour of the plant played a decisive role (connection of large public buildings to ensure a certain base load; influence on public opinion).

- Reporting by the press was largely friendly, and this may have influenced the attitudes of the local population (attention, pride) and discouraged opposition.

The current situation and prospects of the BDH plant Rankweil are favourable. At the time of writing (Dec 2005), the plant manager had on his desk some 60–80 applications from individuals and enterprises who want to be connected to the BDH grid but can not yet be considered (Nöckl, 2005a, b). One reason for this backlog is a recent decision by the Bürgergemeinschaft that only buildings along the main pipeline and only such that can be expected to be cost effective are to be connected, and that no major plant extension will be pursued in the coming years. The remaining heat capacity of the existing pipeline system is around 700 kWe, and the remaining boiler capacity about 500 kW; there is still scope for further supply expansion by optimising the load dispatch through buffering (intermediate heat storage).

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