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Economic and CO_2 mitigation impacts of promoting biomass heating systems: an input-output study for Vorarlberg, Austria

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ABSTRACT. This paper reports on an empirical investigation about the economic and CO2 mitigation impacts of bioenergy promotion in the Austrian federal province of Vorarlberg. We study domestic value added, employment and fiscal effects by means of a static input-output analysis. The bioenergy systems analysed comprise biomass district heating, pellet heating, automated wood chips heating systems, logwood stoves and boilers, ceramic stoves, and buffer storage facilities. The results indicate that gross economic effects are significant, both regarding investment and operation of the systems, and that the negative economic effects caused by the displacement of decentralised systems might be in the order of 20--40%. Finally, CO2 mitigation effects are substantial, contributing already in 2004 around 35% of the 2010 CO2 mitigation target of the Land Vorarlberg for all renewables set for 2010.

KEYWORDS. Input-output analysis, Value added, Employment, Bioenergy

1. INTRODUCTION

An increased use of energy from biomass helps to mitigate CO2 emissions and import dependence on fossil fuels, typically primary energy policy goals, as well as to reap secondary benefits, such as forest restructuring, the creation of employment in rural or remote areas, and capacity building for innovative export technologies and services.

Austria has a long tradition in the use of wood for energy and other purposes, and is one of the leading countries regarding the modern use of bioenergy today. It is a country rich in forestland (3.96 million hectares or 47% of the total land area), and the share of biomass in total energy use of about 11% is ranking third in Europe (Finland: 17%; Sweden: 14%).

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By the end of 2003 more than eight hundred mostly rural biomass district heating (BDH) plants were in operation, with an installed thermal capacity exceeding 1 GW_{th} (Furtner and Haneder, 2006; Sedmidubsky, 2004; Madlener, in press).[1]

Vorarlberg is the smallest and westernmost of the nine Austrian federal provinces (Bundesländer). Approximately one third of the land area of Vorarlberg is covered with forests (90’000 hectares out of a total area of 2’601 km^2), about half of which is protection forest against avalanches, and landslides. The government of Vorarlberg has been promoting various kinds of biomass energy technologies since 1993 in a dedicated program (“Schwerpunktprogramm Biomasse”), mainly by means of non-refundable capital grants. In the Energy Concept Vorarlberg 2010, the goal was stipulated to increase the use of biomass from 1996 to 2010 by 30% (AVLR, 2001),[2] thus raising the share of biomass for heating purposes from 15% to about 20%. The sustainable theoretical wood energy potential of Vorarlberg in terms of final energy has been estimated at some 850--900 GWh per annum, the present yearly technical potential at around 650--700 GWh (VKW, 1999). In 2003, some 545 GWh or about 80% of this technical potential have already been used, compared to 472 GWh in 1996 (70%). In terms of total final energy consumption of Vorarlberg (1996: 8.4 TWh, 2003: 10.7 TWh), and despite a substantial increase in the absolute level of biomass use, the share of biomass nevertheless decreased from approximately 5.6% in 1996 to 5.0% in 2003 (cf. AVLR, 2004a).

In 2005 the governmental administration of the Land Vorarlberg has commissioned a study, in which the macroeconomic consequences of this bioenergy promotion program and the CO_2 emissions avoided were evaluated by means of a static input-output (I-O) analysis (Madlener and Koller, 2005). In this paper we report on this study, in which domestic value added, employment and fiscal effects of bioenergy promotion in Vorarlberg since their inception in 1993 were scrutinised both in absolute (cumulative) and in relative (per €1 million of investment or grant) terms. The bioenergy systems covered by the study comprise BDH systems and various kinds of small-scale systems:

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[1] The term “biomass” in this paper mostly refers to woody biomass only.

[2] Compared to the reference year 1996, the Energy Concept Vorarlberg 2010 foresees a target increase of final energy supplied from all kinds of renewable energy sources but hydropower of 63%, i.e. from 540 GWh to 880 GWh p.a. (cf. AVLR, 2001, p.79). The targeted increase of 340 GWh is expected to come from three main sources: biomass systems (+115 GWh), solar thermal collectors (+140 GWh), and heat pumps (+85 GWh), respectively.

pellet heating, automated wood chips heating, logwood stoves and boilers, ceramic stoves, and buffer storage facilities, respectively.

The paper is organised as follows. Section 2 contains a description of the methodology used. Section 3 summarises the current biomass energy promotion schemes of the Land Vorarlberg, while section 4 reports on the diffusion of large-scale and small-scale bioenergy systems in Vorarlberg. Section 5 describes the data used for the analysis and assumptions made. Section 6 reports on the empirical results, and section 7 summarises and concludes.

2. METHODOLOGY

Static I-O analysis (Leontief, 1953, 1986) is a frequently used method for assessing value added, employment and fiscal effects. A principal distinction is between primary and secondary effects; the former can be divided further into direct and indirect effects. *Primary effects* are effects that are directly related to a particular investment. The value added from the investment induces higher income that is at least partly used for consumption or investment (in contrast to savings), which in turn yields additional value added, employment, and income. *Secondary effects* arise from consumption or investment generated from additional income. The main primary effects, referred to as *direct effects*, arise from the demand for goods and services in the branches of the economy that are directly affected by an economic activity. The economic activities caused in those branches in turn require intermediate inputs, so that ultimately many branches of the economy are involved. Effects caused by such production interrelatedness along the value chain are typically referred to as *indirect effects* (sometimes also as *multiplicative effects*). Figure 1 provides a graphical overview of the different effects just discussed and their relationship to each other.

With the help of I-O tables and the above-mentioned effects *multipliers* for value added and employment can be calculated. These multipliers show by how much output, value added, and employment in a branch of the economy change if an additional unit of demand arises.

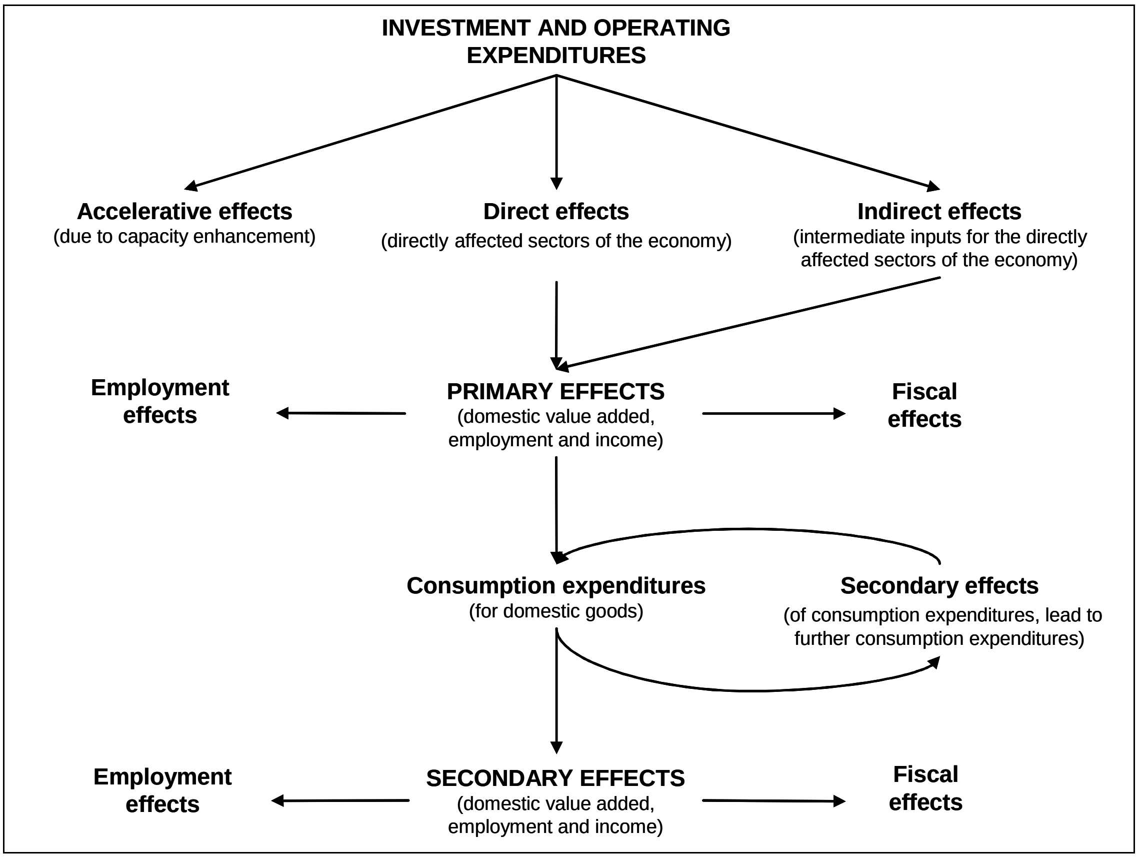

Figure 1. Overview of the effects considered in the I-O analysis.

Source: Madlener and Koller (2005), modified

A further important distinction is that between *gross and net effects*. Since investments are shifted from one branch of the economy to another (in our case, e.g., from conventional fossil fuel heating to modern bioenergy heating systems), some *displacement effects* occur as well. Put differently, if induced structural change happens (e.g. a switch from fossil to bioeneregy systems due to a dedicated bioenergy promotion scheme), positive effects in one or several areas of the economy are diminished by negative effects in other areas of the economy. These negative impacts may take the form of displaced value added or employment effects. If additional taxes have to be collected for funding a particular policy programme, this will affect the net income and thus the budget of the firms/households, thus reducing the amount available for investment or consumption. Finally, if subsidy schemes are involved, opportunity costs arise because public funds (e.g. in the form of non-refundable capital grants) are invested for a particular purpose that are, consequently, no longer available elsewhere. Finally, there may also be adverse effects on competitiveness (local firms may see themselves forced to move their production to somewhere else with a more favourable tax system), so that one could speak of a ‘competition effect’ (cf. Häder and Schulz, 2005).

While I-O analysis is an important method for estimating the economic impact of different investments. The standard I-O approach has some important shortcomings, though, that are summarised in the following (cf. Leontief, 1986). These need to be kept in mind, especially when interpreting the results from such analysis.

- *Constant returns to scale and linear limitational production function.* The connection between input factors and output is assumed to be strictly proportional (i.e. if output is raised by a certain factor, then all input factors rise by the same factor). Thus technical progress and changes in the production structure are neglected. Linearity of the production function implies that the input coefficients are independent of the relative prices.
- *No substitution possibilities and homogeneity of the input factors*. There is no opportunity for substitution among the input factors used in the production process. Therefore, a product can only be produced by a specific combination of input factors, since otherwise another product would be produced.
- *Under-utilisation of the economy*. All effects considered are computed for an economy that is not running at its full capacity, i.e. economic branches use spare capacities and do not have to invest in any capacity expansion. If this assumption does not hold, an accelerator effect must be taken into account (cf. Figure 1).[3]
- *Constancy of input coefficients over time.* The compilation of detailed I-O tables is very demanding. Therefore, I-O tables are often published with a delay of several years, and not for every single year. In the underlying study, the latest I-O table for the Austrian economy available to us was for the year 2000, published in 2004 (cf. Statistics Austria, 2004).

At the sub-national level of analysis, if possible, a multi-regional modelling I-O approach should be adopted (Tiebout, 1957, 1968, 1969; Miernyk et al., 1970; Kipnis, 1976).[4]

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[3] Accelerator or capacity effects, used in dynamic I-O models, reflect the amount by which investments rise due to an increase in macroeconomic demand, given there are capacity shortages.

[4] In a sub-national model for a single area the openness of the economy poses a further serious problem, since a large proportion of the area’s intermediate output is simply assigned to exports (and, similarly, a

However, in doing so, resource costs can dramatically increase, while inaccuracies may still persist (e.g. Jones et al., 1973; Leven, 2006; among others). If no regional I-O table is available, as in the present case, then in a strict sense no regional impacts can be computed. However, since the I-O tables have import/export quotas for each sector of the economy, it can be computed how much of the total impact is domestic, and roughly estimated what domestic impact has arisen in the region (e.g. data permitting, by evaluating the domiciles of the firms involved in a particular project and their business activities).

For the calculation of the effects in a concrete case, total investment has to be broken down first and allocated to the different sectors of the economy concerned (with the help of the I-O table), yielding the primary value added effect.[5] Second, by deducting depreciation and taxation of the goods, it is possible to calculate gross values of wages, salaries, and entrepreneurial income. From these gross values taxes and social security payments have to be deducted. Then, taking into account the savings and import quotas, the domestic consumption expenditures can be calculated that are related to the investment under investigation. Finally, the effect on the fiscal revenues is computed by multiplying the calculated incomes with the relative share of government expenditure to GNP.

3. BIOMASS ENERGY PROMOTION IN VORARLBERG

In order to promote renewable energy use, the government of the Land Vorarlberg offers non-refundable capital grants for the installation of biogas, heat pump, biomass, photovoltaic and solar thermal systems. Biomass systems, that is biomass district heating (BDH) plants "with a communal character" and various types of small-scale biomass heating (SSBH) systems, have been promoted since 1993 in a dedicated programme ("Schwerpunktprogramm Biomasse").[6] In 2004, some 30% of all funds spent the promotion of renewable energy investments were allocated to biomass systems. Additionally to these financial incentives, the Land Vorarlberg also provides

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large proportion of inputs to imports). Construction of a multi-regional I-O model is a remedy to this problem, but requires massive resource input (e.g. Dewhurst et al., 1991).

[5] Note that the same procedure and logic applies if operating and maintenance (O&M) costs of an investment are considered.

[6] Biomass systems run by commercial enterprises can, under certain conditions, receive capital grants from federal sources (see also Madlener, in press, an references therein).

complementary measures, such as the provision of targeted information, counselling, and the organisation of training and education for planners and installers, among others.

Table 1 provides an overview of the main features of the three different kinds of promotion schemes for BDH systems currently in use in Vorarlberg: (1) grants for pre-feasibility studies; (2) capital grants for the construction or expansion of BDH systems with a communal character; and (3) grants for BDH grid connections (paid to private households directly). As can be seen, pre-feasibility studies are subsidised at 30% of the eligible costs up to a maximum amount of €2'200.[7] Capital grants for the construction or extension of a BDH plant are capped at 35% of the total eligible investment costs. The level of promotion for connections to a BDH grid ranges from €150-300 per kW, depending on the type of the existing system to be replaced, and is also limited to 35% of the eligible cost.

The capital grants paid by the Land Vorarlberg until June 2005 (BDH plants) and December 2004 (SSBH systems) respectively sum up to €17.8 million (€8.6 million of basic grants plus €2.8 million of additional grants for the use of forest residue in the case of BDH plants,[8] and €6.4 million for SSBH systems).[9]

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[7] Compared to the other subsidy categories, grants paid for pre-feasibility studies have been negligible, amounting to €4'258 in 2000, €2'200 in 2002, and €10'942 in 2004; no such grants were paid in 2001 and 2003 (Vögel, 2005). In contrast, capital grants for BDH grid connections, which are administered under the heading SSBH systems, are non-negligible in volume (up to 12/2004 about €452'000 in total). They rank fifth among the eleven SSBH promotion categories considered, and account for a relative share of 7.1% of all SSBH grants.

[8] Under certain conditions BDH plants can receive an increased capital grant (max. 45% instead of 35%) if forest residue is used. These conditions are: (1) Use of forest residue over a period of at least ten years (proof by contractual evidence); (2) the forest residue used has to comply with the Austrian standard ÖNORM M7133 (concerning logwood and branches from forestry or residue from landscape conservation without pre-treatment); (3) the volume share of forest residue must not be lower than 15% p.a. Half of the additional grant for the use of forest residue are paid upon project completion, the other half after the elapse of five years and provision of evidence that all conditions have actually been met (AVLR, 2005a,b). Note that under certain conditions, as already reported in Table 2, extra grants are also paid for small-scale wood chips heating systems (AVLR, 2004b,c).

[9] The grants paid are from a number of different sources. Apart from the means provided by the Land Vorarlberg there are several federal sources of funding and the so-called 'requirement-allocated funds' (Bedarfszuweisungen; see footnote 9). As of June 2005, the total amount of grants paid for bioenergy systems amounted to €30.5 million, of which federal means accounted for €8.9 million, requirement-allocated funds €2.5 million, and EU funds €1.3 million.

Table 1. Overview of the promotion schemes of the Land Vorarlberg for biomass district heating plants

Pre-feasibility studies	Construction or expansion of BDH plants	Grid connection
30% of eligible costs, max. €2’200	35% of eligible investment costs	150 €/kW heat load in existing central heating systems and in new buildings and 300 €/kW heat load for changes from single stove or electrical heating or systems without existing heat distribution systems, respectively. Max. 35%.

Source: AVLR (2005a,b)/Madlener and Koller (2005), modified

Table 2 gives a compact overview of the subsidies that are currently offered for small-scale biomass systems. For further details, including a complete list of current and previous biomass energy promotion directives for Vorarlberg, see Madlener and Koller (2005). As can be seen, capital grants for small-scale biomass heating systems range from €800 and €2’200 for single family dwellings, depending on the type of system and type of building concerned, and are defined as a two-part tariff for multi-family houses (€1’000--1’500 per building plus €500--600 per apartment, depending on the biomass system to be installed). Again, they limited to 35% of the total eligible investment costs. A contribution of €100--200 to the service check after two heating periods is granted as well.

In terms of the relative shares of subsidies paid from 1/1993--12/2004 for different types of heating systems, logwood heating systems and buffer storages account for 36.4% (1’800 systems), pellet heating systems 27.2% (596 systems), wood chips heating systems 14% (266 systems), subsequently installed buffer storages 9% (550 systems), connections to BDH grids 7.1% (309 systems), central ceramic stoves 2.4% (91 systems), central stoves 1.7% (64 systems), tiled stoves with chimney installations 1.1% (67 systems), single stoves 0.4% (34 systems), commercial wood chips and pellet heating systems 0.3% (3 systems), and single ceramic stoves 0.2% (16 systems). Note that because some promotion schemes have been phased out (e.g. subsequent buffer storage installation and ceramic stoves with chimney in 2000), and because certain types of heating systems have diffused the market rapidly in recent years (e.g. pellet heating systems), these relative shares can be expected to change considerably over time.

Table 2. Overview of the promotion schemes of the Land Vorarlberg for small-scale bioenergy heating systems

	Ceramic and logwood stoves (individual heating)	Ceramic and logwood stoves (central heating)	Logwood heating with buffer storage	Wood chips heating system	Pellet heating system
One-time capital grant	€800	€1'700	SFH[4]: €1'200, MFC[5]: €1'000 per building and €500 per apartment	SFH[4]: € 2'200, MFC[5]: € 1'500 per building and €600 per apartment	SFH[4]: € 2'200, MFC[5]: €1'500 per building and €600 per apartment
Special clauses		€100 service cheque[1,2]	€100 service cheque[2], €200 for boilers with Lambda-control[3]	€1'000 per building extra if forest wood chips are used (cooperative systems only)	
Max. grant (% of eligible investment costs)			35%	35%	35%

Source: AVLR (2004b,c)/Madlener and Koller (2005), modified

Notes: as of June 2005. [1] for central logwood stoves only if manually fed; [2] cheque for a service inspection after two heating periods; [3] or technically equivalent installation; [4] SFH = single-family houses; [5] MFC = multi-family houses and cooperative systems ('Gemeinschaftsanlagen'). Cooperative systems are micro-grids supplying heat to at least two residential buildings.

Figure 2 shows the temporal development of investments and capital grants for BDH systems. The 7.5 MW BDH plant built in the famous tourist resort Lech am Arlberg, the largest of its kind in Vorarlberg, accounts for the distinct peak in 1999. As can be seen, requirement-allocated funds[10] are substantial, while EU funding accounts for a very small portion only.

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[10] The so-called 'requirement-allocated funds' (Bedarfszuweisungen) are sourced by an earmarked share (currently 12.7%) of the community funds form the total national budget (federal nation/federal provinces/communities), which is held back and disposed of by the Länder (cf. Finanzausgleichsgesetz -- FAG, 2005).

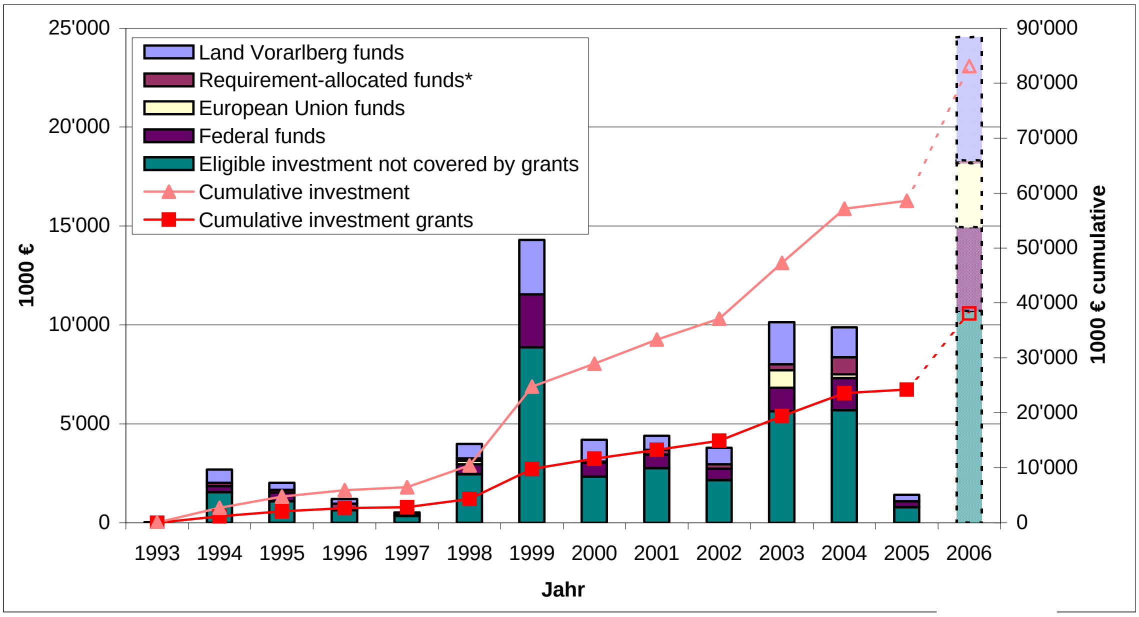


Figure 2. Development of investments and capital grants for BDH systems in Vorarlberg, annual and cumulative, 1/1993--6/2005 (with projections for 2006 and beyond, based on filed projects as of Jun 2005).

Source: Madlener and Koller (2005), modified

Note: * see footnote 9

Figure 3 shows the temporal development of investments and capital grants for the various types of SSBH systems promoted. The cumulative representation shows that the development was even more continuous than it was the case for the BDH plants, which are lower in number and much more heterogeneous.

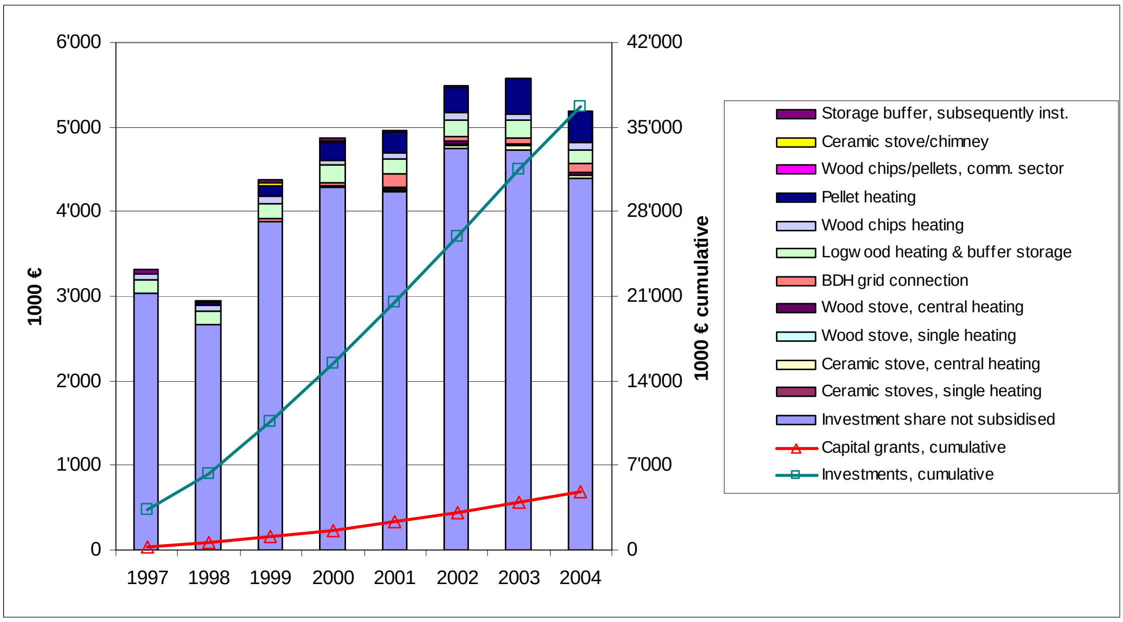


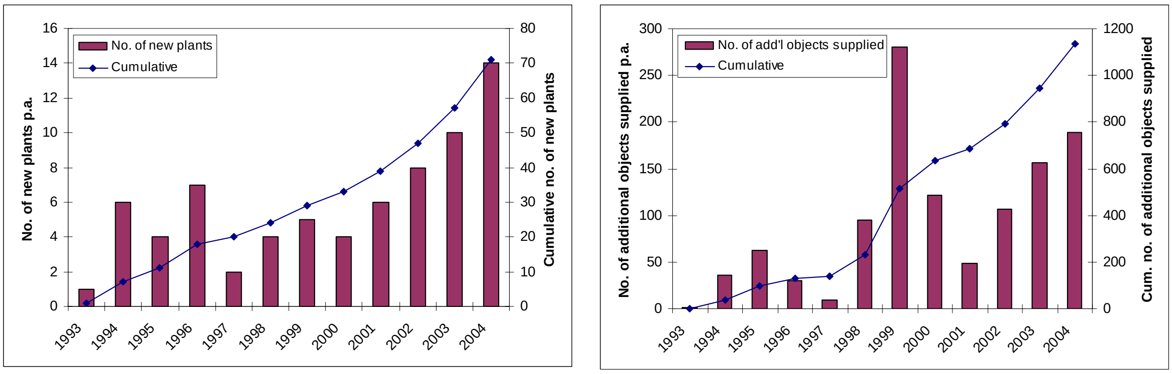
Figure 3. Development of investments and capital grants for small-scale biomass heating systems in Vorarlberg, annual and cumulative, 1997--2004.

Source: Madlener and Koller (2005), modified

4. DIFFUSION OF BIOMASS PLANTS IN VORARLBERG

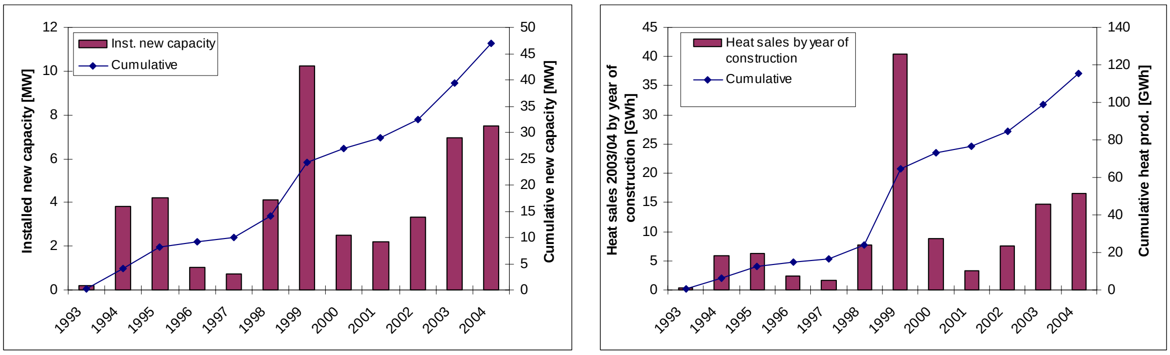
Geographically, BDH systems are widely spread over the Vorarlberg territory, often located in rural and/or mountainous areas with large forest areas and no access to the natural gas grid (cf. Madlener, forthcoming).[11] As of June 2005, the size structure of the 71 BDH systems in operation in Vorarlberg was as follows: 24 plants (34%) had an installed thermal capacity of 200 kW or less, 19 plants (27%) between 201--500 kW, 17 plants (24%) between 501--1’000 kW, eight plants (11%) between 1’001 kW and 2 MW, two plants (3%) between 2’001 kW and 4 MW, and one plant (1%) above 4 MW.

Figure 4 shows the diffusion of BDH plants in Vorarlberg over time and for four different indicators: (1) number of new plants (panel a); (2) number of new objects supplied (panel b); (3) installed new thermal capacity (panel c); and (4) heat sales in 2003/04 by year of construction of the plants (panel d). Here again, the distinct 1999 peaks in panels (b)--(d) are caused by the 7.5MW BDH plant in Lech am Arlberg.



(a) Number of new plants

(b) Number of additional objects supplied



(c) Installed new capacity

(d) Heat sales 2003/04 by year of construction

Figure 4. Diffusion of BDH systems in Vorarlberg, various characteristics, 1993--2004 (*N* = 71).

Source: Madlener and Koller (2005), modified

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[11] According to the main natural gas supplier of Vorarlberg, VEG, currently some 280’000 (or 75% of the total of 373’000) inhabitants of Vorarlberg live in areas with access to the natural gas grid (cf. www.veg.at/images/karte_gemeinden_gross.gif).

Figure 5 depicts the temporal development of the number of subsidised SSBH systems in Vorarlberg (3’796 in total until Dec 2004). It can be seen that many different categories of SSBH systems have been funded over time. Note, however, that as the promotion directives were updated from time to time, the promotion of some of the technologies and systems has been ceased and replaced or supplemented by the promotion of others (e.g. the promotion of pellet heating systems, which was introduced not until 1997, or the phase-out of the subsidies for subsequently installed buffer storages in 2000).

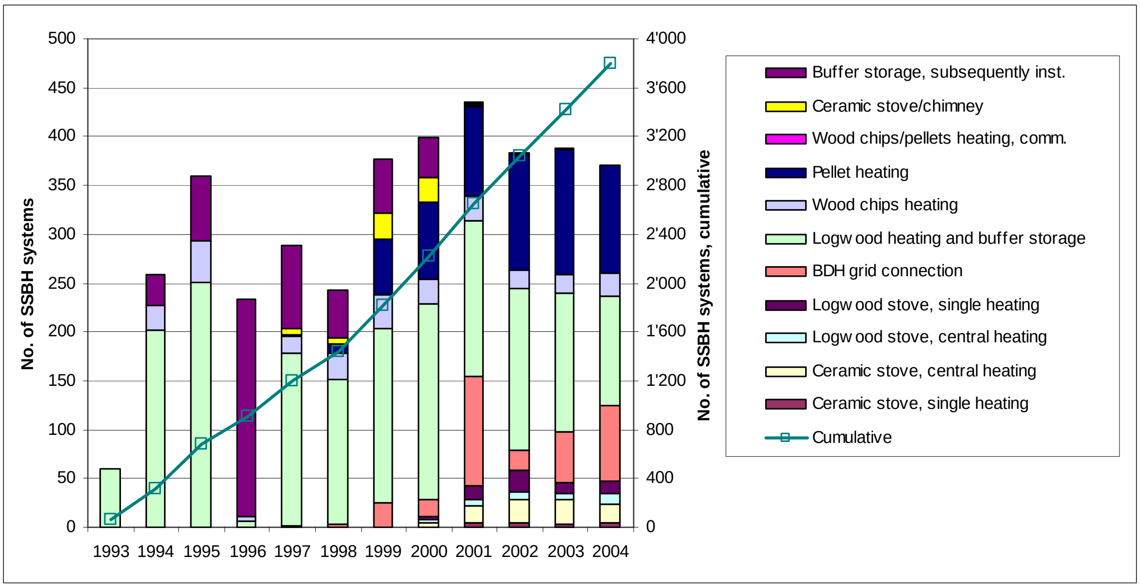

Figure 5. Development of the number of subsidised small-scale biomass heating systems in Vorarlberg, by system category, 1993--2004 (*N* = 3’796).

Source: Madlener and Koller (2005), modified

5. DATA USED

The data set used is unpublished and has been compiled from various sources. It comprises data both for BDH systems and for different categories of SSBH systems that have received subsidies under the “Schwerpunktprogramm Biomasse”. The data for conducting our research were kindly provided by the governmental administration of the Land Vorarlberg. In what follows, we provide some details as to the particular kind and structure of the data that were available to us.

5.1 Plant data

The data base for BDH systems contains information about the type and capacity of the plants, the number of connected buildings, the sum of investments (broken down by several plant components), the total amount of capital grants paid (subdivided by the various sources of origin), and the year of construction. It contains data from the beginning of the promotion scheme (Jan 1993) until the cut-off date of our investigation (Jun 2005).

The annual data set for SSBH systems includes the number of systems promoted in each category, the total amount of investment, and the amount of government aid granted. Since the investment data for the period 1993 to 1997 are incomplete, we had to linearly extrapolate them for these years.

First, we allocated investments to various economic activities and goods, respectively. By subtracting capital that is invested abroad, we were able to compute absolute (cumulated) and specific effects (per million € invested). To this end, we employed the latest I-O table for the Austrian economy for the year 2000, which mostly features 57 goods and 58 activities (Statistik Austria, 2004).

5.2 Capital grants data

As mentioned above, BDH systems are promoted in three different ways: (1) grants for the preparation of pre-feasibility studies; (2) capital grants for the construction or extension of BDH plants; and (3) capital grants for BDH grid connections. Since pre-feasibility studies only account for a negligible amount of the funds spent and thus are of little relevance to our investigation, they were factored out from the analysis.

5.3 Biomass fuel statistics

An estimate for the annual consumption of biomass fuel has only been available for BDH systems, obtained from an annual (unpublished) biomass survey conducted by the governmental administration of the Land Vorarlberg. We linearly extrapolated the data for the years 1993--1999, because reliable statistics for BDH plants were only recorded for 2000 and thereafter. There are no reliable wood fuel statistics for SSBH systems, as a large fraction of the owners of wood heating systems use fuelwood from their own forest,[12] with the exception of pellet heating systems, for which fuel consumption is recorded on an annual basis by the government of Vorarlberg, thus enabling evaluation.

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[12] For the case of logwood heating, a survey by the governmental administration of the province of Vorarlberg conducted in 1999 among 375 owners of SSBH systems revealed that 65% of all fuelwood used in small-scale logwood heating systems was taken from own forest (Groß, 1999).

5.4 Data on displaced systems

In the underlying study we also computed the displacement effects that arise from foregone investments that would have occurred through the replacement of aged decentralised heating systems at the end of the life cycle, and capital stock losses due to the early retirement of decentralised heating systems. Starting from a detailed list of displaced decentralised systems per BDH plant and stylised costs for various size classes of fossil decentralised systems (derived from a reference cost calculation tool kindly provided by the governmental administration of the Land Vorarlberg[13]), we determined the approximate economic value of the displaced systems (only taking into account investment). In total 1’236 decentralised heating systems were replaced by connecting the buildings concerned to one of the 71 BDH plants, 129 of which were in new buildings (10.4%) and 243 of which were decentralised plants with an installed thermal capacity of more than 100 kW (19.7%). The average installed capacity is 88 kW, with a minimum of 3 kW and a maximum of 1’200 kW (i.e. the distribution is heavily skewed to the right).

For the calculations of the displacement effects, we made several assumptions, including a discount rate of 5% for discounting the investment costs over n periods. Variable n denotes the number of time periods into the future until replacement of the decentralised conventional system would have occurred under ‘normal’ circumstances, assuming an average plant lifetime of all displaced decentralised heating systems considered of 20 years. For decentralised heating systems that were replaced at an age of less than ten years, we assumed that these could be sold in a well-functioning second-hand market, so that capital losses can be neglected.

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[13] This (MS Excel-based) calculation tool has been developed by Kommunalkredit Austria (today Kommunalkredit Public Consulting, KPC), a special purpose bank domiciled in Vienna that administers several federal programs for promoting the environment and sustainable energy use. It was adapted by the governmental administration of the Land Vorarlberg for assessing the eligibility of applications for capital grants for BDH projects, and in particular to calculate the cost of the alternative (i.e. displaced) decentralised fossil-fueled heating system. The reason is that the sum of all capital grants paid (i.e. from all funding sources) must not exceed the difference between the eligible cost of the BDH system and the reference cost of the alternative decentralised fossil heating system (AVLR, 2005a,b).

6. EMPIRICAL RESULTS

6.1 Value added, employment, and fiscal effects

6.1.1 Investment impacts

Table 3 summarises the results from the analysis of the investment-related effects. It can be seen that the diffusion of biomass systems (BDH plants from 1/1993--6/2005 and small-scale biomass systems from 1/1993--12/2004) have caused an economic impulse that yielded a gross value added of €92.9 million, an employment effect of 1’580 person-years, and a fiscal effect of €23.3 million.

Table 4 summarises the results per invested million € (and per million € of capital grants), while Table 5 reports on the effects for BDH plants that were either under construction or planned, as of Jun 2005, and for which grants are offered by the Land Vorarlberg. The results show that the impacts caused per million € invested vary only little across technologies, and that the planned and not yet completed projects will cause significant additional effects.

Table 3. Estimated value added, employment and fiscal effects induced per €1 million of investment or €1 million of capital grant, cumulative gross values [€, person-years]

	Per € 1 million of **investments** induced gross effects				
	Value added (VA), primary effect			VA, second.	**VA, total**
[€]	Direct	Indirect	Total		
Ceramic and logwood stoves	483’122	265’714	748’836	324’878	**1’073’714**
Logwood heating and buffer storage systems	475’795	238’539	714’335	309’909	**1’024’244**
Wood chips heating systems	459’204	229’843	689’047	298’938	**987’985**
Pellet heating systems	462’088	230’982	693’070	300’684	**993’754**
BDH grid connection	520’318	265’915	786’232	341’102	**1’127’334**
BDH plants	499’370	268’897	768’267	333’308	**1’101’574**
	Employment, primary effect			Empl., second.	**Empl., total**
[person-years]	Direct	Indirect	Total		
Ceramic and logwood stoves	8.5	4.7	13.2	5.7	**18.9**
Logwood heating and buffer storage systems	8.9	4.4	13.3	5.8	**19.0**
Wood chips heating systems	8.5	4.3	12.8	5.5	**18.3**
Pellet heating systems	8.6	4.3	12.9	5.6	**18.5**
BDH grid connection	9.9	5.0	14.9	6.5	**21.3**
BDH plants	8.1	4.2	12.4	5.4	**17.7**
	Fiscal effects (FE), primary			FE, second.	**FE, total**
[€]			Total		
Ceramic and logwood stoves			188’176	81’639	**269’815**
Logwood heating and buffer storage systems			179’506	77’878	**257’384**
Wood chips heating systems			173’152	75’121	**248’273**
Pellet heating systems			1’264’479	548’586	**1’813’065**
BDH grid connection			197’574	85’716	**283’290**
BDH plants			193’059	83’757	**276’817**

(continued overleaf)

(Table 3 -- cont.)

	Per € 1 million of **capital grants** induced gross effects				
	Value added (VA), primary effect			VA, second.	**VA, total**
[€]	Direct	Indirect	Total		
Ceramic and logwood stoves	3’850’895	2’117’972	5’968’866	2’589’553	**8’558’419**
Logwood heating and buffer storage systems	4’920’207	2’466’739	7’386’946	3’204’777	**10’591’724**
Wood chips heating systems	2’829’195	1’416’084	4’245’279	1’841’786	**6’087’066**
Pellet heating systems	2’725’846	1’362’554	4’088’400	1’773’725	**5’862’125**
BDH grid connection	1’747’572	893’119	2’640’690	1’145’646	**3’786’336**
BDH plants (all funding sources)	1’208’000	650’473	1’858’473	806’286	**2’664’759**
BDH plants (Land Vorarlberg funds only)	2'551’472	1'373’894	3'925’366	1'702’994	5'628’360
	Employment, primary effect			Empl., second.	**Empl., total**
[person-years]	Direct	Indirect	Total		
Ceramic and logwood stoves	68.1	37.2	105.3	45.7	**151.0**
Logwood heating and buffer storage systems	91.5	45.8	137.3	59.6	**196.9**
Wood chips heating systems	52.6	26.2	78.8	34.2	**113.0**
Pellet heating systems	50.8	25.3	76.1	33.0	**109.1**
BDH grid connection	33.1	16.8	49.9	21.7	**71.6**
BDH plants (all funding sources)	19.7	10.2	29.9	13.0	**42.9**
BDH plants (Land Vorarlberg funds only)	41.6	21.6	63.2	27.4	**90.6**
	Fiscal effects* (FE), primary			FE, second.	**FE, total**
[€]			Total		
Ceramic and logwood stoves			1’499’927	650’733	**2’150’661**
Logwood heating and buffer storage systems			1’856’279	805’334	**2’661’614**
Wood chips heating systems			1’066’804	462’826	**1’529’630**
Pellet heating systems			1’027’381	445’723	**1’473’104**
BDH grid connection			663’584	287’891	**951’475**
BDH plants (all funding sources)			467’019	202’613	**669’632**
BDH plants (Land Vorarlberg funds only)			986’412	427’948	**1'414’361**

Source: Madlener and Koller (2005), modified

Notes: The grants per €1 million of investment are as follows: tiled and logwood stoves €125’000, logwood heating and buffer storage facilities €97’000, automated wood chips heating systems €162’000, pellet heating systems €169’000, BDH grid connections €298’000, BDH plants €415’000. From these, the calculated subsidy quotas can be derived as: tiled and logwood stoves 7.97; logwood/buffer storage facility 10.34; wood chips heating systems 6.16; pellet heating systems 5.90; BDH grid connection 3.36; BDH systems 2.41. Note that only the investments and promotion data from 2000 to 2005 have been included, since the data are only complete since 1997, and investment data are only available on an annual basis since 2000.

The fiscal effects investigated are divided into total primary and secondary effects only (i.e. we were unable to distinguish between direct and indirect primary effects). Based on the assumption that taxes are mainly imposed on private income, the share of private income on the value added (58.2%) was multiplied with it and also with the average ratio of government expenditures to gross national product (averaged over the period 1993--2004) of 43.2%.

[*] Observation period: 1/1993--6/2005 for BDH plants and 1/1993--12/2004 for SSBH systems

Table 4. Estimated value added, employment and fiscal effects induced in absolute terms by investment in subsidised biomass systems, cumulative gross values [€, person-years]

	Through **investments** in biomass systems (incl. plants under construction or in the planning phase) and through **operation** of biomass and pellet heating system induced gross values				
	Value added (VA), primary effect			VA, second.	**VA, total**
[€]	Direct	Indirect	Total		
Ceramic and logwood stoves	1’371’450	754’290	2’125’741	922’238	**3'047’979**
Logwood heating and buffer storage systems	9’629’700	4’827’837	14’457’537	6’272’306	**20’729’843**
Wood chips heating systems	1’682’275	842’021	2’524’296	1’095’149	**3’619’446**
Pellet heating systems	3’354’912	1’677’002	5’031’914	2’183’062	**7’214’976**
Fuel use in pellet heating systems	264’419	192’963	457’382	198’432	**655’814**
BDH grid connection	703’615	359’591	1’063’206	461’265	**1’524’471**
TOTAL	*17’006’371*	*8’653’704*	*25’660’076*	*11’132’452*	***36’792’529***
BDH plants	25’730’195	13’854’972	39’585’167	17’173’760	**56’758’927**
Fuel use in BDH plants	7’289’567	5’426’203	12’715’770	5’516’652	**18’232’422**
Operation of BDH plants	2’550’106	1’704’797	4’254’902	1’845’961	**6’100’863**
TOTAL	*35’569’860*	*20’985’965*	*56’555’824*	*24’536’366*	***81’092’190***
BDH plants under construction[a]	158’211	82’042	240’252	104’232	**344’484**
BDH plants in the planning phase[a]	11’145’847	6’043’403	17’189’250	7’457’441	**24’646’691**
TOTAL	*11’304’058*	*6’125’445*	*17’429’502*	*7’561’673*	***24’991’175***
	Employment, primary effect			Empl., second.	**Empl., total**
[person-years]	Direct	Indirect	Total		
Ceramic and logwood stoves	24.2	13.3	37.5	16.3	**53.8**
Logwood heating and buffer storage systems	179.1	89.6	268.7	116.6	**385.3**
Wood chips heating systems	31.3	15.6	46.8	20.3	**67.2**
Pellet heating systems	62.5	31.2	93.7	40.6	134.3
Fuel use in pellet heating systems	5.4	3.9	9.4	4.1	**13.5**
BHD grid connection	13.3	6.8	20.1	8.7	**28.8**
TOTAL	*315.8*	*160.4*	*476.2*	*206.6*	***682.9***
BDH plants	419.5	217.5	637.0	276.4	**913.4**
Fuel use in BDH plants	148.0	109.6	257.7	111.8	**369.5**
Operation of BDH plants	17.2	11.5	28.7	12.4	**41.1**
TOTAL	*584.7*	*338.6*	*923.4*	*400.6*	***1’324.0***
BDH plants under construction[a]	2.8	1.4	4.2	1.8	**6.0**
BDH plants in the planning phase[a]	177.4	92.8	270.2	117.2	**387.4**
TOTAL	*180.2*	*94.2*	*274.4*	*119.0*	***393.4***
	Fiscal effects (FE) primary			FE, second.	**FE, total**
[€]			Total		
Ceramic and logwood stoves			534’181	231’751	**765’932**
Logwood heating and buffer storage systems			3’633’061	1’576’179	**5’209’240**
Wood chips heating systems			634’335	275’202	**909’537**
Pellet heating system			1’264’479	548’586	**1’813’065**
Fuel use in pellet heating systems			114’936	49’864	**164’801**
BDH grid connection			267’175	115’912	**383’087**
TOTAL			*6’448’167*	*2’797’494*	***9’245’662***
BDH plants			9’947’429	4’315’626	**14’263’054**
Fuel use in BDH plants			3’195’369	1’386’290	**4’581’659**
Operation of BDH plants			1’069’222	463’875	**1’533’097**
TOTAL			*14’212’016*	*6’165’789*	***20’377’804***
BDH plants under construction[a]			60’373	26’193	**86’566**
BDH plants in the planning phase[a]			4’319’518	1’873’994	**6’193’512**
TOTAL			*4’379’891*	*1’900’187*	***6’280’078***

Source: Madlener and Koller (2005), modified

Note: [a] based on filed projects as of 30 Jun 2005

6.1.2 Operational and maintenance impacts

Similar studies often focus on the (gross) effects caused by investment only. We will show that the effects caused by the operation and maintenance (O&M) of the plant, and by fuel use, are also significant and should therefore not be neglected in such analyses.

The use of biomass results in economic effects with a very regional character. This is particularly true with respect to the provision of biomass fuel for BDH plants.[14] Apart from biomass harvesting and collection and wood residue processing operations, expenses for plant operation have to be accounted for as well. These include the cost of electricity consumption, wages of the operating personnel, service and maintenance costs, repair costs, costs of the vehicle fleet, expenses for public relations etc.

Table 5 depicts a summary of the gross effects caused from the O&M of the plants. Note that due to data limitations, we had to restrict ourselves to the impact of biomass fuel used in BDH plants and in pellet heating systems, and of O&M expenses in BDH plants (i.e. the effects are probably underestimated).

Table 5. Estimated value added, employment and fiscal effects from fuel input and plant operation, cumulative gross values [€, person-years]

	Value added [€]	Employment [person-years]	Fiscal effect [€]
Impact of fuel use in BDH plants and small-scale pellet heating systems			
Fuel use in BDH plants	18’232’400	370	4’581’700
Fuel use in small-scale pellet heating systems	655’800	14	164’800
Operation of BDH plants	6’100’900	41	1’533’100

Source: Madlener and Koller (2005), modified

Note: Observation period 1/1993--12/2004

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[14] The provision of biomass fuel is predominantly local for several reasons: First, transportation costs account for a high share of total costs. Second, some stipulations in the promotion directives demand that predominantly local biomass is used. Third, the local population normally has an interest that local, regional, or at least domestic energy resources are being used. Finally, many of the operators and/or owners of biomass systems own forest, and thus have an incentive to use their own wood fuel resources (e.g. local forest-owning communities, such as Buerger- and Agrargemeinschaften, owning or having a certain share in BDH plants, or supplying small-scale users).

6.2 Displacement effects

Our calculations show that total investment in BDH plants of €58.3 million displaced investment expenses of approximately €19 million and 'destroyed' about €2.4 million of the capital stock due to premature retirement of functioning decentralised heating systems. Therefore, the displacement effects concerning investments in decentralised systems -- the only ones considered in our investigation -- turn out to be in the order of 30--50%, leading to negative value added, employment, and fiscal effects of 20--40%. The reason for this difference in the impact lies in the fact that crowding out mainly takes place for the manufacturing and installation of the heating systems, while there is hardly any crowding out concerning construction (realisation of a BDH plant typically requires the construction of a stand-alone building, while a decentralised heating system does not). Also, the multipliers for construction are generally higher than those for manufacturing and installation. These results are similar to the ones obtained by Schönbäck et al. (1996, p.160f.) in an earlier study on Austrian BDH plants, who calculate a displacement effect of 48%. For further details on the calculations, assumptions and data used see section 5.4 above and Madlener and Koller (2005).

6.3 CO_2 mitigation effects

In view of the ambitious CO_2 mitigation targets of the Land Vorarlberg contained in the Energy Concept 2010 (cf. AVLR, 2001, p.137f.), the question of how much CO_2 can be avoided by biomass systems is paramount. Figure 6 depicts the avoided CO_2 emissions through BDH plants over time for the period 1993 until 2004, both by type of wood fuel input per year and on a cumulative basis. As can be seen, the estimated net CO_2 mitigation effect in 2004 has been slightly more than 35'000 t CO_2, and the net cumulative CO_2 mitigation effect over the period 1993--2004 about 180'000 t CO_2. 'Net' in this context means that heat losses in the heat distribution grid and the use of fossil auxiliary energy for the supply of bioenergy are taken into account in the CO_2 savings calculation (see Madlener and Koller, 2005, for further details).[15] This amounts to some 35% of the 2010 target for renewable energies set out in the Energy Concept Vorarlberg 2010 (AVLR, 2001).

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[15] We have assumed that district heating grid losses are on average 15%, and that the shares of (fossil) auxiliary energy used for oil extraction, processing and transporting is 20% and for biomass harvesting and transporting 5%, respectively.

For simplicity, it was assumed that biomass systems exclusively substitute for systems based on heating oil extra-light. This can be justified on the ground that few BDH plants are built in areas where access to the natural gas grid exists, and that most of the existing decentralised heating systems in areas not supplied by natural gas are fuelled by heating oil extra-light. In other words, our estimate is indicative only and represents an upper bound to the actual CO_2 emissions avoided.

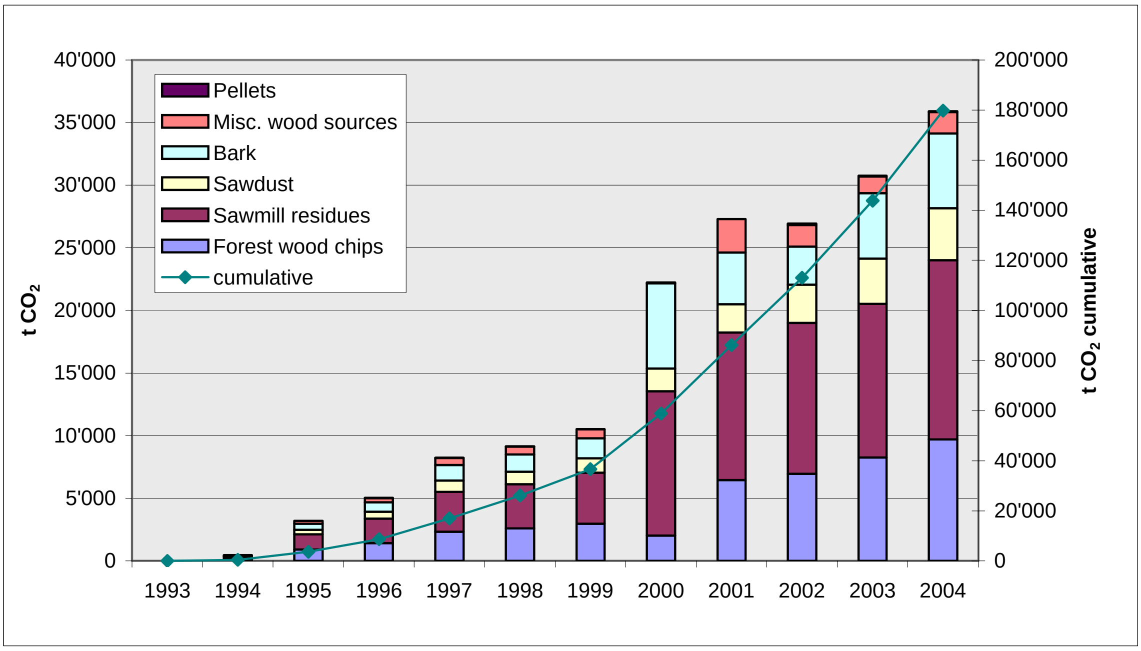

Figure 6. Avoided CO_2 emissions by means of BDH systems, by fuel input, annual and cumulative, 1993--2004.

Source: Madlener and Koller (2005), modified

As far as SSBH systems are concerned, due to data limitations, we have only been able to study the CO_2 mitigation effect of the pellet heating systems. For the period from 1/1997 until 12/2004, we estimated the cumulative gross CO_2 avoidance to be around 6’800 tons. If auxiliary fossil energy use for the provision of the biomass fuels are taken into account, we calculate that the net effect turn out to be around 6’500 t. In 2004, the CO_2 mitigation impact of pellet heating systems has been 2’000 t, thus contributing a further 2% to the 2010 CO_2 reduction target of 102’000 t attributable to renewable energy use foreseen in the Energy Concept of the Land Vorarlberg (AVLR, 2001). Hence in total biomass contributes some 37% to the 2010 CO_2 mitigation target for all renewable energy sources already in 2004.

7. SUMMARY AND CONCLUSIONS

In this paper we have summarised the methodology and results of an I-O study on the economic impacts and CO_2 mitigation effects of promoting bioenergy systems in the Austrian province of Vorarlberg. We find that the gross effects in terms of value added, employment, and fiscal impact are substantial, and that the negative economic impact accruing from the displacement of investments in decentralised systems may be in the order of 20--40% of the positive value added. Within the scope of the study undertaken, we were unable to assess the net (or net) effects on employment, competitiveness, and the fiscal budget. Such a study, though challenging, would be a fruitful avenue for further research.

Particularly, between January 1993 and June 2005 the Land Vorarlberg has subsidised 71 biomass district heating systems (incl. extensions) with €11.4 million. An additional €12.4 million have been provided by federal bodies and EU institutions. These subsidies have helped to trigger an investment volume of €58.3 million. Additionally, some 3’800 small-scale systems of various types have been promoted with €6.4 million between January 1993 and December 2004. In this case the investment volume triggered was €36.7 million.

The main findings from the I-O study can be summarised as follows:

- Investment, operation and maintenance of BDH schemes have triggered important economic effects. In particular,
    - total investment in BDH systems has induced an estimated gross value added of €92.9 million, an employment effect of 1’580 person-years, and fiscal effects of €23.3 million.
    - per million € of subsidy granted by the Land Vorarlberg a value added of €5.6 million, 91 person-years of employment, and a fiscal effect of €1.4 million are generated (if all subsidies are taken into consideration these values are reduced to €2.7 million, 43 person-years, and €0.7 million, respectively).
- The *amount of subsidy granted per million € of investment* is: €125’000 for tiled and other stoves, for logwood/storage systems €97’000, wood chips heating €162’000, pellet heating €169’000, BDH grid connections €298’000, and for BDH systems 415’000. The corresponding subsidy quotas (subsidy rates)[16] are: 12.5% (7.97) for

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[16] The subsidy quota is calculated as the percentage share of the subsidy paid relative to total investment costs, the subsidy rate is the reciprocal value.

tiled and other stoves, 9.7% (10.34) for logwood/storage systems, 16.2% (6.16) for wood chips heating systems, 16.9% (5.9) for pellet heating systems, 29.8% (3.36) for BDH grid connections, and 41.5% (2.41) for BDH systems.

- The *BDH plants (and plant extensions) still under construction or in the planning phase* (as of June 2006), for which subsidies will be granted, are expected to cause an additional value added of €24.6 million, an employment effect of 387 person-years, and a fiscal effect of €6.2 million.
- The *use of biomass in BDH and pellet systems* has caused a value added of €18.2 million, an employment effect of 370 person-years, and a fiscal effect of €4.6 million.
- Operation of the 71 BDH plants has caused an estimated value added of €6.1 million, employment effects of 41 person-years, and a fiscal effect of €1.5 million.
- The CO_2 mitigation effects are substantial, too. In 2004 alone, the BDH plants have reduced CO_2 emissions by about 36’000 t (35% of the total target from renewable energy sources for 2010), while pellet heating systems have contributed another 2% to the target in that year, a share which is rapidly rising due to the rapid market diffusion of pellet heating systems. On a cumulative basis (BDH systems since 1993, pellet heating systems since 1997), these two types of heating systems have helped to avoid 180’000 t and 6’500 t of CO_2 emissions, respectively.

Due to a lack of data the present study could only address the displacement effects to a limited extent. Calculations based on detailed object lists (i.e. buildings connected to BDH systems and decentralised heating systems replaced) indicate that the displacement effects caused by crowding out of decentralised systems may actually be rather moderate, in a range between 20--40% for the value added, employment, and public budget, and for displaced investments in the order of 30--50%. The displaced investments are estimated at €19 million, the capital destroyed by premature retirement of decentralised heating equipment at €2.4 million. The main reasons are: (1) decentralised systems are only replaced successively over time; (2) replaced decentralised systems can be expected to be traded in a second-hand market (no capital destruction); (3) BDH systems tend to be more capital-intensive (partly due to the grid, which is usually constructed by local firms); and (4) in our analysis construction of the building is only relevant for the BDH plant and not for the displaced decentralised system, and construction exhibits higher multipliers than other relevant activities.

It must be emphasised once again that the interpretation of the results should be made with great care only, since the use of a static I-O analysis with (unaltered) national coefficients in a regional context is a crude approach, and the bias of the estimates may be large. It is quite obvious that methodological improvements in this respect are desirable, but will come at the burden of large resource cost. Within the scope of the study reported here, such kind of refined analysis has been totally out of reach.

Finally, the aim of the study reported here did not comprise an analysis of the cost effectiveness of the promotion scheme (incl. a quantification of the windfall gains and opportunity cost of the financial means used, and possibly a comparison with the other provinces which run similar schemes). This would be another fruitful avenue for further research.

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REFERENCES

Adensam, H., Rohrbacher, H., Suschek-Berger, J., Schiffert, Th., Rakos, C., Schmidl, H., 2000. Kachelöfen im nachhaltigen Energiekonzept, Berichte aus der Energie- und Umweltforschung 2/2000, Bundesministerium für Verkehr, Innovation und Technologie (BMVIT), Wien.

AVLR, 2001. Neuigkeiten aus der Zukunft. Energiekonzept Vorarlberg 2010. Schlussbericht (News from the Future. Energy Concept Vorarlberg 2010. Final Report, in German). Amt der Vorarlberger Landesregierung, Bregenz, März.

AVLR, 2004a. Energiebericht 2004. Amt der Vorarlberger Landesregierung, Bregenz, Dezember.

AVLR, 2004b. Informationsblatt der Vorarlberger Landesregierung zur Förderung von Biomasse-Kleinanlagen. Amt der Vorarlberger Landesregierung, Bregenz (valid from 1/2005--12/2006).

AVLR, 2004c. Richtlinien der Vorarlberger Landesregierung zur Förderung von Biomasse-Kleinanlagen im Zusammenhang mit der verstärkten Nutzung von Biomasse zu energetischen Zwecken (Schwerpunktprogramm Biomasse). Amt der Vorarlberger Landesregierung, Bregenz (valid from 1/2005--12/2006).

AVLR, 2005a. Informationsblatt der Vorarlberger Landesregierung zur Förderung von Biomasse-Nahwärmeprojekten (Ausführungsrichtlinie) Amt der Vorarlberger Landesregierung, Bregenz. (valid from 7/2005--6/2008).

AVLR, 2005b. Richtlinien der Vorarlberger Landesregierung für die Gewährung von Zuschüssen zu Maßnahmen im Zusammenhang mit der verstärkten Nutzung von Biomasse zu energetischen Zwecken durch Biomasse-Nahwärmeprojekte (EU-notifiziert) (valid from 7/2005--6/2008).

Dewhurst, J.H.L., Jensen, R.C., Hewings, G.J.D., eds., 1991. Regional Input-Output Modelling: New Developments and Interpretations, Avebury, Brookfield/Vermont.

FAG, 2005. Bundesgesetz, mit dem der Finanzausgleich für die Jahre 2005 bis 2008 geregelt wird und sonstige finanzausgleichsrechtliche Bestimmungen getroffen werden (Finanzausgleichsgesetz 2005 -- FAG 2005), BGBl. Nr. 156/2004, zuletzt geändert BGBl. Nr. 105/2005.

Furtner, K., Haneder, K., 2006. Biomasse-Heizungserhebung 2005, Niederösterreichische Landes-Landwirtschaftskammer, St. Pölten.

Groß, A., 1999. Schriftliche Umfrage des Amtes der Vorarlberger Landesregierung zu den vom Land Vorarlberg geförderten Stückholzheizungen, Bregenz (unpublished).

Groß, A., 2004. Biomasse hat Zukunft! Positionspapier zur energetischen Biomassenutzung in Vorarlberg, Energieinstitut Vorarlberg, Dornbirn, Februar.

Haas, R., Kranzl, L., 2002. Bioenergie und Gesamtwirtschaft. Analyse der volkswirtschaftlichen Bedeutung der energetischen Nutzung von Biomasse für Heizzwecke und Entwicklung von effizienten Förderstrategien für Österreich. Berichte aus der Energie- und Umweltforschung 12/2003, Bundesministerium für Verkehr, Innovation und Technologie (BMVIT), Wien.

Häder, M., Schulz, E., 2005. Beschäftigungswirkungen der Förderung erneuerbarer Energien, Energiewirtschaftliche Tagesfragen, 55(7): 472-475.

Jones, L.L., Sporleder, T.L., Mustafa, G., 1973. A source of bias in regional input-output models estimated from national coefficients, Annals of Regional Science, 42(3): 477-507.

Kipnis, B.A., 1976. Local versus national coefficients in constructing regional input-output tables in small countries: a case study in Northern Israel, Journal of Regional Science, 16(1): 93-99.

Leontief, W., 1953. Studies in the Structure of the American Economy -- Theoretical and Empirical Explorations in Input-Output Analysis, Oxford University Press, New York/Oxford.

Leontief, W., 1986. Input-Output-Economics, 2nd Ed., Oxford University Press, New York/Oxford.

Leven, C., 2006. Distortions in estimating net benefits of regional development projects, Annals of Regional Science, 40(1): 191-201.

Madlener R. (in press), Innovation diffusion, public policy, and local initiative: the case of wood-fuelled district heating systems in Austria, Energy Policy (available online since 24 Aug 2006).

Madlener R., Koller M., 2005. Evaluierung der wirtschaftlichen Auswirkungen der Förderung von Biomasse-Anlagen durch das Land Vorarlberg. Schlussbericht, Studie des Centre for Energy Policy and Economics (CEPE) an der ETH Zürich im Auftrag des Amtes der Vorarlberger Landesregierung, Zürich, Dezember.

Miernyk, W.H., Shellhammer, K.L. et al., 1970. Simulating Regional Economic Development, Heath, Lexington/Mass.

Schönbäck, W., Adensam, H., Kosz, M., 1996. Ökonomische Evaluation der Biomassenutzung. Endbericht, Studie des Instituts für Finanzwissenschaft und Infrastrukturpolitik der Technischen Universität Wien im Auftrag des Bundesministeriums für Wissenschaft, Verkehr und Kunst, Wien, Juli.

Statistik Austria, 2004. Input-Output-Tabelle 2000 (CD-ROM und Dokumentation), Statistik Austria, Wien, Februar.

Tiebout, C.M., 1957. Regional and interregional input-output models: an appraisal, Southern Economic Journal, 24: 140-147.

Tiebout, C.M., 1968. Regional and interregional input-output models: an appraisal, in L. Needleman (ed.), Regional Analysis, Penguin, Baltimore, pp.86-96.

Tiebout, C.M., 1969. An empirical regional input-output projection model: The State of Washington 1980, The Review of Economics and Statistics, 51(3): 334-340.

VKW, 1999. Energieholzpotential in Vorarlberg -- unter besonderer Berücksichtigung des Holzbedarfes für Biomasseheizwerke (energy potential in Vorarlberg – with special consideration of the wood demand of biomass district heating plants; in German), Vorarlberger Kraftwerke AG, Bregenz (unpublished mimeo).

Vögel, C., 2005. Personal communication with Christian Vögel, Amt der Vorarlberger Landesregierung, Bregenz, 15 Nov 2005.

CEPE Working Papers

1999

Scheller A. (1999), Researchers' Use of Indicators. Interim Report of The Indicator Project. CEPE Working Paper No. 1, Centre for Energy Policy and Economics (CEPE), Zurich, September.

Pachauri S. (1999), A First Step to Constructing Energy Consumption Indicators for India. Interim Report of the Indicator Project. CEPE Working Paper No. 2, Centre for Energy Policy and Economics (CEPE), Zurich, September.

Goldblatt D. (1999), Northern Consumption: A Critical Review of Issues, Driving Forces, Disciplinary Approaches and Critiques. CEPE Working Paper No. 3, Centre for Energy Policy and Economics (CEPE), Zurich, September.

2000

Aebischer B. und Huser A. (2000), Monatlicher Verbrauch von Heizöl extra-leicht im Dienstleistungssektor. CEPE Working Paper Nr. 4, Zürich, Centre for Energy Policy and Economics (CEPE), September.

Filippini M. and Wild J. (2000), Regional Differences in Electricity Distribution Costs and their Consequences for Yardstick Regulation of Access Prices. CEPE Working Paper No. 5, Centre for Energy Policy and Economics (CEPE), Zurich, May.

Christen K., Jakob M., und Jochem E. (2000), Grenzkosten bei forcierten Energiesparmassnahmen in Bereich Wohngebäude - Konzept vom 7.12.00. CEPE Working Paper Nr. 6, Centre for Energy Policy and Economics (CEPE), Zürich, Dezember.

2001

Luchsinger C., Wild J., and Lalive R. (2001), Do Wages Rise with Job Seniority? – The Swiss Case. CEPE Working Paper No. 7, Centre for Energy Policy and Economics (CEPE), Zurich, March.

Filippini M., Wild J., and Kuenzle M. (2001), Scale and Cost Efficiency in the Swiss Electricity Distribution Industry: Evidence from a Frontier Cost Approach. CEPE Working Paper Nr. 8,

Centre for Energy Policy and Economics (CEPE), Zurich, June. Jakob M., Primas A., und Jochem E. (2001), Erneuerungsverhalten im Bereich Wohngebäude – Auswertung des Umfrage-Pretest. CEPE Working Paper Nr. 9, Zürich, Centre for Energy Policy and Economics (CEPE), Oktober.

Kumbaroglu G. and Madlener R. (2001), A Description of the Hybrid Bottom-Up CGE Model SCREEN with an Application to Swiss Climate Policy Analysis. CEPE Working Paper No. 10, Centre for Energy Policy and Economics (CEPE), Zurich, November.

Spreng D. und Semadeni M. (2001), Energie, Umwelt und die 2000 Watt Gesellschaft. Grundlage zu einem Beitrag an den Schlussbericht Schwerpunktsprogramm Umwelt (SPPU) des Schweizerischen National Fonds (SNF). CEPE Working Paper Nr. 11, Centre for Energy Policy and Economics (CEPE), Zürich, Dezember.

2002

Filippini M. and Banfi S. (2002), Impact of the new Swiss Electricity Law on the Competitiveness of Hydropower, CEPE Working Paper No. 12, Centre for Energy Policy and Economics (CEPE), Zurich, January.

Filippini M., Banfi S., and Luchsinger C. (2002), Deregulation of the Swiss Electricity Industry: Implication for the Hydropower Sector, CEPE Working Paper No. 13, Centre for Energy Policy and Economics (CEPE), Zurich, April.

Filippini M., Hrovatin N., and Zoric J. (2002), Efficiency and Regulation of the Slovenian Electricity Distribution Companies, CEPE Working Paper No. 14, Centre for Energy Policy and Economics (CEPE), Zurich, April.

Spreng D., Scheller A., Schmieder B., und Taormina N. (2002), Das Energiefenster, das kein Fenster ist, CEPE Working Paper Nr. 15, Centre for Energy Policy and Economics (CEPE), Zürich, Juni.

Fillippini M. and Pachauri S. (2002), Elasticities of Electricity Demand in Urban Indian Households, CEPE Working Paper No. 16, Centre for Energy Policy and Economics (CEPE), Zurich, March.

Semadeni M. (2002), Long-Term Energy Scenarios: Information on Aspects of Sustainable Energy Supply as a Prelude to Participatory Sessions, CEPE Working Paper No. 17, Centre for Energy Policy and Economics (CEPE), Zurich, Juli.

Müller A. (2002), Finding Groups in Large Data Sets, CEPE Working Paper No. 18, Centre for Energy Policy and Economics (CEPE), Zurich, October.

2003

Farsi M. and Filippini M. (2003), Regulation and Measuring Cost Efficiency with Panel Data Models: Application to Electricity Distribution Utilities, CEPE Working Paper No. 19, Centre for Energy Policy and Economics (CEPE), Zurich, January.

Banfi S., Filippini M., and Müller A. (2003), Rent of Hydropower Generation in Switzerland in a Liberalized Market, CEPE Working Paper No. 20, Centre for Energy Policy and Economics (CEPE), Zurich, January.

Müller A. and Luchsinger C. (2003), Incentive Compatible Extraction of Natural Resource Rent, CEPE Working Paper No. 21, Centre for Energy Policy and Economics (CEPE), Zurich, January.

Jakob M. and Madlener R. (2003), Exploring Experience Curves for the Building Envelope: An Investigation for Switzerland for 1970-2020, CEPE Working Paper No. 22, Centre for Energy Policy and Economics (CEPE), Zurich, March.

Banfi S., Filippini M., and Hunt, L. C. (2003), Fuel Tourism in Border Regions, CEPE Working Paper No. 23, Centre for Energy Policy and Economics (CEPE), Zurich, March.

Semadeni M. (2003), Energy Storage as an Essential Part of Sustainable Energy Systems: A Review on Applied Energy Storage Technologies, CEPE Working Paper No. 24, Centre for Energy Policy and Economics (CEPE), Zurich, May.

Pachauri S. and Spreng D. (2003), Energy Use and Energy Access in Relation to Poverty, CEPE Working Paper No. 25, Centre for Energy Policy and Economics (CEPE), Zurich, June.

Aruga K. (2003), Differences in Characteristics of Religious Groups in India: As seen from Household Survey Data, CEPE Working Paper No. 26, Centre for Energy Policy and Economics (CEPE), Zurich, August.

Madlener R. and Wickart M. (2003), The Economics of Cogeneration Technology Adoption and Diffusion: A Deterministic Model, CEPE Working Paper No. 27, Centre for Energy Policy and Economics (CEPE), Zurich, December.

Madlener R. (2003), Modelling the Adoption and Diffusion of Decentralised Energy Conversion Technologies with Hazard Rate Models, CEPE Working Paper No. 28, Centre for Energy Policy and Economics (CEPE), Zurich, December.

Madlener R., Robledo C., Muys B., Hektor B., and Domac J. (2003), A Sustainability Framework for Enhancing The Long-Term Success of LULUCF Projects, CEPE Working Paper No. 29, Centre for Energy Policy and Economics (CEPE), Zurich, December.

2004

Madlener R., Kumbaroglu G., and Ediger V. S. (2004), Modeling Technology Adoption as an Irreversible Investment Under Uncertainty: The Case of the Turkish Electricity Supply Industry, CEPE Working Paper No. 30, Centre for Energy Policy and Economics (CEPE), Zurich, February.

Jakob M. (2004). Entwicklung des Erdgasabsatzes zwischen 1990 und 2000 und Perspektiven bis 2010 aus Sicht der Schweizerischen Gasversorgungsunternehmen – Weiterführender dokumentierender Arbeitsbericht der empirischen Arbeiten. CEPE-Working-Paper No 31, Centre for Energy Policy and Economics (CEPE), Zurich, April.

Farsi M., Filippini M., and Greene W. (2004), Efficiency Measurement in Network Industries: Application to the Swiss Railway Companies, CEPE Working Paper No. 32, Centre for Energy Policy and Economics (CEPE), Zurich, June.

Farsi M., Filippini M., and Kuenzle M. (2004), Cost Efficiency In Regional Bus Companies: An Application of Alternative Stochastic Frontier Models*, CEPE Working Paper No. 33, Centre for Energy Policy and Economics (CEPE), Zurich, July.

Banfi S., Filippini M., and Luchsinger C. (2004), Resource Rent Taxation – A New Perspective for the (Swiss) Hydropower Sector, CEPE Working Paper No. 34, Centre for Energy Policy and Economics (CEPE), Zurich, August.

Kumbaroglu G., Madlener R., and Demirel M. (2004). A Real Options Evaluation Model for the Diffusion Prospects of New Renewable Power Generation Technologies, CEPE Working Paper No. 35, Centre for Energy Policy and Economics (CEPE), Zurich, September.

Farsi M., Filippini M., and Kuenzle M. (2004). Cost Efficiency in the Swiss Gas Distribution Sector, CEPE Working Paper No. 36, Centre for Energy Policy and Economics (CEPE), Zurich, October.

Wickart M., Madlener R. (2004). Risk and Uncertainty in Industrial Large-Scale Cogeneration Investment, CEPE Working Paper No. 37, Centre for Energy Policy and Economics (CEPE), Zurich, December

Cuiping L., Jochem E., Madlener R., and Zhang Y. (2004). Status of Wind Power Development and Policies in China, CEPE Working Paper No. 38, Centre for Energy Policy and Economics (CEPE), Zurich, December.

2005

Fillippini M., Farsi M. and Fetz A. (2005). Benchmarking Analysis in Electricity Distribution, CEPE Working Paper No. 39, Centre for Energy Policy and Economics (CEPE), Zurich, March. Jochem E. (2005). An Agenda for Energy and Material Efficiency Policy – An Element of

Technology Policy for a More Sustainable Use of Natural Resources. CEPE Working Paper No. 40, Centre for Energy Policy and Economics (CEPE), Zurich, March. Banfi, S., Farsi, M., Filippini, M., Jakob, M. (2005). Willingness to Pay for Energy-Saving Measures in Residential Buildings. CEPE Working Paper No. 41, Centre for Energy Policy and Economics (CEPE), Zurich, April

Farsi M., Filippini M., Pachauri S. (2005). Fuel Choices In Urban Indian Households, CEPE Working Paper No. 42, Centre for Energy Policy and Economics (CEPE), Zurich, May.

Farsi M., Filippini M.(2005). A Benchmarking Analysis of Electricity Distribution Utilities in Switzerland, CEPE Working Paper No. 43, Centre for Energy Policy and Economics (CEPE), Zürich, June.

Filippini M., Luchsinger C. (2005). Economies of Scale in the Swiss Hydropower Sector, CEPE Working Paper No. 44, Centre for Energy Policy and Economics (CEPE), Zürich, June.

Gao W., Madlener R., Zweifel P. (2005). Promoting Renewable Electricity Generation in Imperfect Markets: Price vs. Quantity Control, CEPE Working Paper No. 45, Centre for Energy Policy and Economics (CEPE), Zurich, December.

Madlener R., Gao W. (2005). Renewable Energy Policy in the Presence of Innovation: Does Pre-Commitment by the Government Matter? CEPE Working Paper No. 46, Centre for Energy Policy and Economics (CEPE), Zurich, December.

2006

Jakob M., Baur M., Ott W. (2006). An Analysis of Direct and Indirect Benefits and Costs of Energy Efficiency Attributes in Residential Buildings, CEPE Working Paper No. 47, Centre for Energy Policy and Economics (CEPE), Zurich, May.

Farsi M., Fetz A., Filippini M. (2006). Economies of scale and scope in local public transportation, CEPE Working Paper No. 48, Centre for Energy Policy and Economics (CEPE), Zurich, April.

Madlener R., Henggeler Antunes C., Dias L. C. (2006). Multi-Criteria versus Data Envelopment Analysis for Assessing the Performance of Biogas Plants, CEPE Working Paper No. 49, Centre for Energy Policy and Economics (CEPE), Zurich, July.

Madlener R., Koller M. (2006). Economic and CO_2 mitigation impacts of promoting biomass heating systems: an input-output study for Vorarlberg, Austria, CEPE Working Paper No. 50, Centre for Energy Policy and Economics (CEPE), Zurich, September

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