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Diffusion of bioenergy in urban areas: socio-economic analysis of the planned Swiss wood-fired cogeneration plant in Basel

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ABSTRACT. The municipal utilities of Basel (IWB) are in the process of building a 30 MW wood-fired CHP plant in the city of Basel, a project idea that was initially propelled by visionaries from the forest sector. The plant is attractive both politically and from a business perspective, as several goals related to the increased use of renewable energy can be achieved simultaneously. Moreover, significant woody biomass resources are awaiting further exploitation in the Basel region, which could help to improve markedly the cost effectiveness of forest maintenance. In this paper we study the history and some of the characteristics of the planned project from a socio-economic perspective. Of particular interest to our study is the early involvement of a large number of stakeholders with different interests. The project constitutes a pioneering project that could serve as an important non-Scandinavian model for similar projects in other parts of Switzerland, but also in Western and Central Europe as a whole. The lengthy decision-making and planning process offers interesting insights into the socio-economic drivers and barriers of large-scale bioenergy projects in urban settings, where wood heating systems are in general not as well established as in the countryside. We find that the interest of regional forest owners to tackle the problem of over-aged and largely unprofitable forests, coupled with a political climate that (1) favours green energy projects and (2) provides incentives for the municipal utility to produce more green energy from sources other than hydropower, have been the two main success factors for developing this particular biomass plant project.

KEYWORDS. Urban biomass use, Wood energy, Cogeneration, Socio-economics, Basel, Switzerland

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1. INTRODUCTION

Urban areas are attractive for centralised bioenergy use for various reasons. First, energy densities tend to be higher than in less populated areas. Second, in many cases an existing district heating network, as well as other infrastructure facilities and services (e.g. for system control or fuel logistics) can be used, thus significantly reducing investment needs. Third, centralised bioenergy cogeneration plants constitute an important opportunity for providing urban residents with access to renewable heat and electricity. Finally, in urban settings large plant sizes are feasible, enabling the exploitation of significant economies of scale and the realisation of high conversion efficiencies and low specific pollutant emission levels. However, despite the local availability of biomass from landscape conservation and other biomass resources that can be used for energy purposes, in most cases at least part of the biomass required has to be transported from the surroundings into the city. This may cause additional traffic and other adverse environmental impacts, and therefore possible opposition from local residents.

Switzerland has considerable forest resources. Many of these are in mountainous and often environmentally sensitive areas where it is necessary to preserve the beauty of the landscape (e.g. for tourism, recreation) or to protect against soil erosion, landslides, and avalanches of different kinds. Measured in roundwood equivalents, total annual wood consumption in Switzerland is around 7 million m^3, whereas the annual increment amounts to some 10 million m^3. In contrast, currently only about 4.5 million m^3 of wood is extracted from Swiss forests. Because of this systematic under-utilisation of the domestic wood resource base -- a latent problem which has been underestimated for many years -- today the average wood density in Swiss forest stands, at 362 m^3/ha, is among the highest in Europe [1]. Over-aged stands suffering from a lack of forest rejuvenation activities and reduced biodiversity lead to severe long-term problems. Barriers to an increased use of wood from Swiss forests include the often difficult terrain, relatively high labour costs, and restrictive regulations (e.g. regarding tree felling and wood harvesting), all of which make domestic wood supply costly in comparison to imports from a very competitive international wood market. Also, in a stagnating industry it is more difficult to undertake necessary investments in innovative technology, and to nurture and maintain an entrepreneurial spirit that could create a new market momentum.

Today, bioenergy plays a relatively minor role in Switzerland: only about 5% (41 PJ) of final energy use is covered by biomass sources, of which wood energy accounts for about

43% [2-4]. However, at the end of the 1990s a special short-term wood energy promotion programme, introduced in response to the devastating effects of storm "Lothar", led to a temporary investment boost.[1] Furthermore, the Swiss Wood Energy Association (Holzenergie Schweiz) has been very active in networking, lobbying, and educating -- and recently even started a dedicated wood energy image campaign. Nevertheless, the public grants offered are widely considered as being too moderate to push the diffusion of bioenergy systems significantly.

Basel is a special case in Switzerland, in that the Canton of Basel-City (BS) and the surrounding Canton of Basel-Land (BL) have both been very active and progressive in operationalising sustainable development in general, and environmental protection and the pursuit of green (energy) policies in particular. In 1998, for instance, the Canton of Basel-City introduced a modern Energy Act [6] that has served as a model for other cantons. The Act contains three important elements for fostering sustainable energy use: (1) an eco-tax; (2) a concession for the promotion of energy efficiency and renewable energy investments, and (3) a solar power exchange (Solarstrombörse). Furthermore, in 2001 the Canton of Basel-City supported the establishment of the Basel Agency for Sustainable Energy (BASE).[2] It has also participated in the project "2000 Watt Society -- Pilot Region Basel", endorsed by the Swiss Federal Institutes of Technology (ETH Zurich, EPF Lausanne, PSI, WSL, EAWAG, and EMPA -- the so-called 'ETH Domain'). This included a project that dealt with wood-fuelled mobility and heating based on biomass gasification technology.[3]

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[1] On 26-27 December 1999, winter storm "Lothar" felled some 13 million m^3 of standing forest, i.e. about three times the regular annual harvest. In reaction to this devastating effect, the Swiss Federal Office of Energy (SFOE) offered investment grants of 45 million Swiss Francs (1 Swiss Franc equals about 0.66 Euros; i.e. the grants amounted to approx. €30 million), which led to the support of 111 wood energy plants (> 100 kW of installed capacity), 194 grid connections, 11 wood energy storage facilities, 3,299 wood firing units (< 100 kW of installed capacity), and 104 feasibility studies. For further details on the Lothar subsidy programme see [5].

[2] BASE is a Collaborative Centre of the United Nations Environment Programme (UNEP). It focuses on promoting and facilitating investment in renewable energy and energy efficiency in both industrialised and developing countries, and provides a turntable for the business and financial communities aimed at fostering the build-up of strategic partnerships and the discussion of investment options. For further information see www.energy-base.org.

[3] The vision of a 2000 Watt Society, propagated by the ETH Council (ETH-Rat) since 1998, aims at reducing long-term per capita energy consumption in developed countries to 2000 Watt, without any need to sacrifice current lifestyles. Further, the 2000 Watt Society aims at decreasing annual emissions of greenhouse gases to one tonne per capita, which is considered sustainable [7].

For a recent account of energy politics in the Canton of Basel-Land see, e.g., UVEK [8], and for the sustainable development strategies of the two cantons see for instance [9] and [10], respectively.

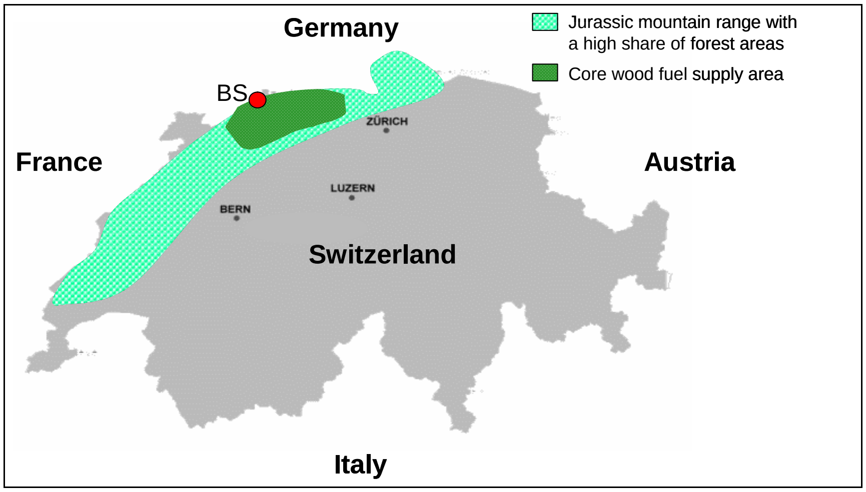

Figure 1. Map of Switzerland with location of the planned wood-fired CHP plant in Basel-City (BS) and the local and regional wood fuel supply area.
Source: Courtesy of WSL, adapted

In both cantons, Basel-City and Basel-Land, there are large untapped woody biomass resources from arboriculture and landscape conservation, but also from unused reserves of hardwood forests (which yield a disproportionately high share of forest residue), only about half of which are currently used for energy purposes (see Figure 1 for a map of Switzerland and the Basel area). An increased utilisation of these resources for bioenergy purposes could help to improve greatly the cost effectiveness of forest maintenance operations. At the same time, the City of Basel has an extensive and well-developed district heating grid, covering an area of about 9 km^2 and supplying some 110'000 inhabitants with heat energy.[4] Politically, both cantons are committed to significantly reduce their CO_2 emissions, in order to contribute to the fulfilment of the Swiss obligation under the Kyoto Protocol (a reduction in greenhouse gas emissions of 8% by 2008/12, relative to 1990 levels) and the Swiss CO_2 Act 2000 [12] (a reduction in CO_2 emissions of 10% by

[4] The district heating grid of IWB is the largest in Switzerland. The heat energy produced annually amounts to some 1,000 GWh, which is distributed over 200 kilometers of grid to the final customers. About half of the energy is produced in the waste incineration plant and a sewage treatment plant; the other half is generated by means of natural-gas-fired steam and hot water boilers [11]. The planned biomass CHP plant is expected to produce some 103 GWh of heat annually.

2010, relative to 1990 levels). The replacement of fossil fuels by biomass, an energy carrier that is essentially greenhouse gas neutral, can effectively contribute to meeting these climate change mitigation targets.

In this paper we describe and analyse the plan of the City of Basel (represented by the municipal utilities -- IWB), in cooperation with the regional association of forest owners (Waldwirtschaftsverband beider Basel -- WbB), to erect a 30 MW wood-fired cogeneration (combined-heat-and-power, CHP) plant with an installed thermal capacity of 25 MW_{th} and an electric capacity of 4 MW_{el}, which would require the use of some 180,000 m^3 (loose) of wood residue (equivalent to 147 GWh). If construction of the plant started in summer 2006, as planned, it could be put into operation by early 2008. A core idea of the project initiators has been to actively involve a variety of stakeholders in project development and financing, including potential wood residue suppliers (e.g. forest owners, horticultural enterprises), local and regional electricity and heat distribution companies other than IWB, large-scale energy consumers (e.g. real estate owners), and others. Following some smaller urban heat-only bioenergy projects realised in other Swiss cities, such as Winterthur, Lausanne, and La-Chaux-de-Fonds (typically 1-5 MW_{th}), the project is an important pioneer project -- also regarding the organisational structure chosen -- that could further pave the way for similar large-scale projects in other Swiss cities as well as cities in other (esp. neighbouring) European countries. An example for such a bandwagon effect is the Swiss capital of Berne, where a plant with a similar concept but even larger size is currently projected. The decision-making and planning process has been lengthy, and offers interesting insights into the socio-economic drivers of and barriers to implementing such a bioenergy project in a densely populated area of a highly developed country where, in contrast to many Scandinavian cities for example, urban wood heating traditions are typically less firmly established than in the countryside.

The remainder of this paper is organised as follows: Section 2 describes the history of the project and the role of key actors involved in the project development process. Section 3 describes the main features of the planned project. Section 4 discusses the drivers of and barriers to the project, and lessons that have been learned so far. Section 5 provides an outlook on further development of the project, and section 6 concludes.

2. A LARGE-SCALE BIOMASS CHP PLANT FOR BASEL: HISTORY OF AN IDEA

The initiative for the realisation of an urban wood-fired cogeneration plant in Basel (dubbed “Holzkraftwerk Basel”) can be traced back to an idea developed by the managing director of the forestry and green area management operations of the Canton of Basel-City, Christoph Zuber. He concretised and communicated the idea jointly with the co-author of this manuscript, Stefan Vögtli, in the form of a two-page project outline in November 2002 [13].[5] The dedication and endurance of these two *pioneers* appears to have been an important success factor in the process of giving birth to this important flagship biomass project for the Basel region and beyond. In particular, from December 2002 until May 2003, these two project initiators contacted a large number of stakeholders in the businesses concerned (especially the municipal utilities of Basel, IWB), society, public administration and politics, in order to introduce the project idea to them and to hear their opinions, comments, and objections. The goal was to establish broad support for the project at a very early stage of development. It became clear that a majority of the foreseen *wood fuel suppliers* (forest owners, forest companies, wood processing industries) were in favour of such a project. Their declared interest was in a sustainable, secure, and long-term development of wood fuel supply in the region. By contrast, *waste wood suppliers* were sceptical with respect to the possibilities of waste wood usage. This was because the waste wood market -- due to limited supply and increasing demand -- has been quite unstable in recent years, which makes predictions of future prices and the security of supply of waste wood a rather difficult undertaking.

In June 2003 a project group was established within WbB. Contact was sought both with specific policy makers, and with large heat consumers as potential customers. *Public authorities*, and especially the Agency for the Environment and Energy (AUE) of the City of Basel, were highly in favour of the project, as were the government of Basel-City and the Swiss Federal Office of Energy (SFOE). The SFOE in particular considers the project as path-breaking for Switzerland and has signalled its willingness to provide some co-funding in the form of a one-off capital grant. Eventually, the *board of directors* of the municipal utilities of Basel, IWB, was willing to take up the idea and to study the techni-

[5] This initiative followed a pre-study commissioned in 2001 by the Agency for the Environment and Energy (AUE) of the City of Basel and the Swiss Association for Wood Energy, in which the possibilities for heat and electricity production from solid biomass using the district heating grid were evaluated [14].

cal and economic feasibility of such a project in detail. In fact, IWB showed a general interest in wood energy as a substitute for fossil fuels and also as a welcome opportunity to enlarge their portfolio of renewable electricity generation assets and green power marketing potential (see section 3.2 for further details on this issue).

In August 2003, IWB commissioned a first feasibility study [15]. The study, completed in January 2004, scrutinised three potential plant locations, all of which form part of existing sites: (1) a waste incineration plant (KVA); (2) a district heating plant (FKW), and (3) a maintenance depot/operating centre (Werkhof) (cf. Fig. 2). The study showed clearly that the location on the site of the existing waste incineration plant (KVA) was by far the most economically viable, in that it showed the lowest investment cost, lowest heat generation cost, and lowest business risk (cf. section 0 for details). In contrast, on the FKW site, the lack of a railway connection made the location unfeasible, since there is a political requirement to deliver at least part of the woody biomass residue to the plant by railway. Hence, in autumn 2003, IWB took the decision to proceed with a more detailed feasibility study on the KVA location and to establish contact with potential co-investors.

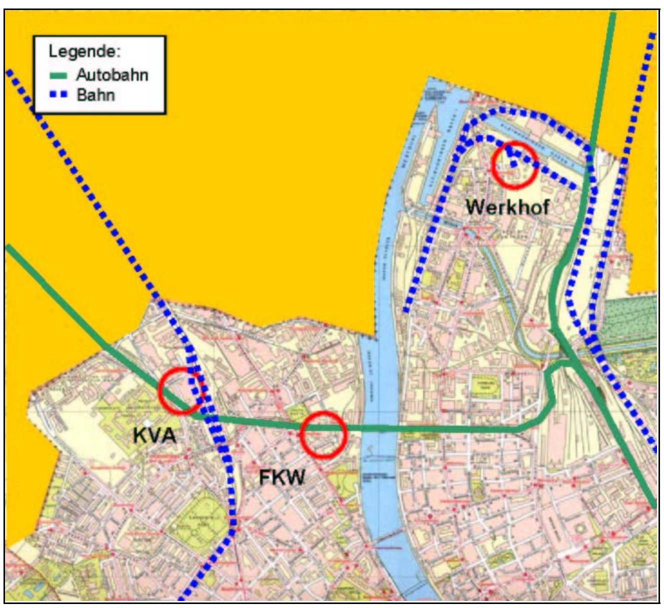

Figure 2. The three potential plant locations scrutinised during the first-stage feasibility study (of which KVA turned out to be by far the most favourable).
Source: Courtesy of Eicher+Pauli, adapted

In June 2004, at an extraordinary general assembly of WbB, the delegates voted in favour of founding a public limited company (Aktiengesellschaft) for the joint marketing of wood products from the regional forests. The new company (dubbed "Holzvermarktungszentrale

Nordwestschweiz AG", HZN AG) will act as a hub between wood suppliers (esp. the forest owners), the wood processing industry, and end-users. The foundation of the company is a reaction to the ongoing market concentration on the wood and wood fuel demand side, i.e. the trend that fewer and larger buyers of wood residue typically meet a rather large number of relatively small suppliers. The foundation was preceded by a two-year phase of capacity building. In the heating season 2003/04, some 22,000 m^3 of forest residue and several thousand tonnes of energy wood from other sources and industrial wood were already marketed via HZN AG. For the medium term future, it is planned that HZN AG will sell around 50% of the annual wood harvest in the region (equivalent to some 100,000 m^3). Also, in June 2004 about 100, mostly public, forest owners of the Northwestern Switzerland region earmarked CHF 6 million (about €4 million) by means of letters of intent for investing into the planned CHP plant, thus expressing their firm commitment.

The project has been accompanied by the Swiss Wood Energy Association ("Holzenergie Schweiz"), the WbB, and the Interest Group Wood Energy Northwestern Switzerland ("IG Holzenergie Nordwestschweiz").[6] A special forest marketing agency (waldmarketing.ch) has also arisen out of the above-mentioned activities, and has been involved ever since in the development process. Established in 2002, waldmarketing.ch is an "advisory and communications office" that (1) provides and maintains momentum; (2) seeks (risk capital) investors for the first phase of investment; (3) takes care of public relations and lobbying for the project; (4) represents the interests of the forest owners, and (5) informs as many people as possible about the project. Overall, there is some evidence that waldmarketing.ch has taken over the role of a change agent.[7]

[6] The IG Holzenergie Nordwestschweiz was founded in 1993 as a non-profit organisation aimed at the energetic use of forestry and industrial wood in Northwestern Switzerland (for further details see www.holzenergie.ch/ignws/).

[7] In the sociological diffusion of innovations literature a change agent has been defined as "an individual who influences clients' innovation-decisions in a direction deemed desirable by a change agency" [16]. Note that so far waldmarketing.ch has been a one-man enterprise, so that in our case the terms "agent" and "agency" are interchangeable.

3. PROJECT DESCRIPTION

3.1. Short description of technical features

IWB faced a need to replace some old oil- and gas-fired boilers. In the course of preparing this replacement investment decision, it also considered the option of producing 10% of the district heat by means of a wood boiler (the benchmark alternative being a natural-gas-fired boiler; [17]). This option turned out to be viable and sufficiently attractive.

Based on the results of the above-mentioned feasibility studies the current plan is to install a 30 MW wood-fired CHP system (a 25 MW steam boiler with grate-firing that produces 35 tonnes of steam per hour at 40 bar and 400º C). The existing steam turbine of the waste incineration plant can also be used by the biomass system, as can certain control and other installations on the site.

The main technical characteristics and components of the planned wood energy system can be briefly summarised as follows (see [15] for further details): *Wood fuel:* The design of the plant will be such that up to 30% of waste wood can be burnt.[8] *Fuel logistics:* The delivery of the wood chips will be undertaken by rail or truck (see section 3.3). *Fuel storage:* there will be a covered silo with a capacity of 4,200 m^3 of loose wood chips, allowing for the separate storage of different wood fuel fractions, and fuel supply of the plant for five days at full load operation. On-site mixing of the various wood fractions is considered advantageous, since by allowing the operator of the plant to directly control the wood fuel mix, it facilitates the use of green residue, waste wood etc. *Conveyor system:* a sliding floor ('Schubboden') allows for an adequate mixture of the various wood chips qualities delivered; conveyor belts will transport the fuel to the intermediate storage compartment feeding the firing unit ('Vorliegesilo'). *CHP unit:* grate stoker furnace (single boiler) with a steam turbine. *Flue gas filtering:* NO_x reduction by flue gas circulation and an SNCR process:[9] fly ash removal by multi-cyclone separator; heavy metal and pollution reduction through injection of activated carbon and lime hydrate; repression of fine particles by fabric filters (cf. section 3.6). *Ash disposal:* the ash silo will be sized such that disposal of the

[8] The Swiss Clean Air Act [18] distinguishes between untreated wood ('naturbelassenes Holz'), wood residue ('Restholz'), waste wood ('Altholz'), and problematic waste wood ('problematische Holzabfälle') (see also [19]). The last-mentioned category will not be used at the Basel plant.

[9] SNCR refers to "Selective Non-Catalytic Reduction", a technology whereby an additive (typically ammonia or urea) is injected into the combustion chamber. The conversion of nitrogen oxides into nitrogen and water, without a catalyst, takes place at temperatures of between 850 and 1,100° C.

bottom ash is required every 1-2 months (the annual amount of bottom ash has been estimated to be between 600-900 t). Fly ash held back by the cyclone separator and the tissue filter is contaminated with heavy metals and has to be disposed of through hazardous waste channels. *Monitoring:* the plant will be monitored from the existing control room of the waste incineration plant (i.e. the new wood-fired plant will be integrated into the control system of the existing plant). Figure 3 depicts the location of the waste incineration plant in the city of Basel, where the planned wood-fired CHP unit will be built.

Figure 3. Favoured location of the planned 30 MW wood-fired CHP unit, forming an integral part of an existing waste incineration plant.
Source: Courtesy of IWB

3.2. Business economics

The economic considerations can be viewed from different angles. Here we take a more holistic view that also includes the wood fuel supply economics as part of the overall project. This makes sense, given that the idea is to supply the plant mainly with wood fuels from the Basel region (Northwestern Switzerland and some neighbouring areas in Southwestern Germany), a self-imposed supply constraint.

As indicated above, wood fuels for the Basel plant could come from different sources, including residue from forestry, sawmills, landscape conservation, and waste wood. Table 1 provides an overview of the expected amounts of wood fuels that could be supplied for the operation of the plant (wood residue and waste wood from the region).

Table 1. Different wood fuel sources available

Assortment	*Share*	*m^3 (loose)*	*Final energy (GWh)*
Untreated wood residue,	70%	128,000	84
of which:			
- Forest residue (assumed mix: 80% hardwood, 20% softwood)	50%	91,000	62
- Residue from sawmills and landscape conservation	20%	37,000	22
Waste wood	30%	55,000	41
Total	*100%*	*183,000*	*125*

Source: [21] adapted

Note: Final energy calculations are based on an assumed fuel conversion efficiency of 85%.

Fuel cost: In 2004, fuel costs were calculated to be around 0.038 CHF/kWh for forest residue, 0.02 CHF/kWh for residue from sawmills and wood from landscape conservation, and zero for waste wood. In the light of the high oil price levels experienced in 2005 (which are expected by most analysts to persist), and given that wood fuel prices are likely to be indexed to the development of the price for heating oil, wood fuel costs are expected to be considerably higher than anticipated in 2004.

Plant investment and O&M cost. As already mentioned, three alternative options were studied in the first feasibility study. Due to different circumstances, in particular the existing infrastructure that could be used to some extent for the wood-fired CHP plant, they differed greatly in cost. Calculations for the three options were made on the following assumptions: (1) a plant lifetime of 25 years; (2) an interest rate (internal rate of return on total capital) of 4.4%; (3) a depreciation period of 25 years;[10] (4) operating costs that include personnel costs equivalent to eight person-years p.a.;[11] (5) 5,500 hours of annual operation (4,900 of which are at full load), and (6) a fuel mix of 80% forest residue and 20% residue from landscape conservation. Table 2 reports some of the main results from this first feasibility study. Note also that these calculations were done for a 25 MW plant (20 MW_{th}, 3.5 MW_{el}).

[10] Calculations in [15] were based on the recommendations contained in the German industry guideline VDI 2067, issued by the Association of German Engineers [20] and replaced by guideline VDI 6025 in 1996.

[11] These also include ash disposal costs (in [21] assumed to be CHF 120/t for bottom ash and CHF 460/t for fly ash), costs for ammonia (CHF 160/t), calcium hydrate (CHF 100/t), and activated carbon (CHF 350/t).

Table 2. Main results from the feasibility study that focused on a 25 MW plant and three possible plant locations

Position	*Option* *KVA*	*FKW*	*Werk-hof*
Investment cost (million CHF)	21	26	36
Heat generation cost (CHF/MWh)	38.2	45.7	57.2
Summary appraisal / Risk assessment (logistics, operation, technical integration, misc. risks)	+	0	0/-

Source: [15]

Notes: + … well suited / low risk; 0 … suited / calculable risk; - … not suited / high risk

A major advantage of the KVA location is that several existing installations can be used, thus reducing investment and operating costs. Moreover, the available logistics channels for different freight carriers (truck, rail, combined roll-on/roll-off container transport) exhibit some reserve capacity. While the FKW location would also allow for the use of some existing facilities (chimney, building), albeit to a lesser extent than for the KVA location, both investment and operating costs turn out to be considerably higher. A major drawback is the lack of railway access. Finally, the Werkhof location is the least attractive of the three, as it would require the erection of a new building and all necessary installations as well as a major adjustment of the logistics (incl. a reorganisation of the road access). Moreover, the distribution pipes for the district heat would have to be reinforced (these costs were not included in the calculations).

Subsidies have not been accounted for, although it is foreseen that an investment subsidy of CHF 6.7 million (initially CHF 2 million were envisaged) will be granted by the Canton of Basel-City. The impact of the expected CO_2 levy, as foreseen in the 2000 Swiss CO_2 Act [12] and currently under debate, is not accounted for in the calculations either.[12] However, it is reckoned that in the case of the introduction of the CO_2 levy in Switzerland, the reduction in CO_2 emissions achievable through the operation of the biomass CHP plant could mean that the entire district heating network of Basel would be exempted from the

[12] The Swiss CO_2 Act 2000 [12] foresees the introduction of (voluntary) *agreements* and *formal commitments*, and -- if these should turn out to be insufficient -- a CO_2 levy (between 35–210 CHF/t of CO_2). An agreement represents a declaration in writing on energy saving or the efficient use of energy, and may contain voluntary measures to be taken. In contrast, formal commitments to the federal government on limiting CO_2 emissions are made by large enterprises, energy-intensive enterprises, or groups of consumers (for a useful recent discussion of these issues in the context of CHP, see for example [22]).

levy [14]. The estimated revenues from plant operation are based on the assumption that a feed-in tariff of CHF 0.15 can be obtained for electricity supplied to the grid, which is the current market price for green power labelled as "naturemade star".[13] The internal revenues for the heat fed into the district heating grid are based on avoided cost of a conventional (natural-gas-fired) heat generation system and have been assumed to be 0.03 CHF/kWh [14]. A further opportunity for additional revenues arises if the green heat produced can be sold at a higher end-user price than conventional heat (the expectation is 0.075 instead of 0.057 CHF/kWh).[14]

For the preferred option (KVA), the investment volume of the wood-fired CHP plant has been estimated to be about CHF 32 million (incl. 10% reserve for unforeseen expenditures, and interest payments of CHF 1 million; cf. Pauli et al., 2004). This amount includes a reserve of 10% for unforeseen expenses and interest payments of CHF 1 million. Annual operating costs have been estimated to be around CHF 4.8 million if a fraction of the fuel input is waste wood, and CHF 6.1 million if only forest residue is used. Furthermore, it has been estimated that the plant would be profitable if about 30% waste wood is used and if a heat price of 38 CHF/MWh can be realised. If only forest residue is used the heat price charged would have to be 51 CHF/MWh. Compared to a natural-gas-fired system, this implies heat generation surplus costs of 400-1,700 CHF/MWh. Sensitivity analyses undertaken in [15] have shown that the required minimum specific heat price is highly sensitive to changes in the feed-in tariff (e.g. at a feed-in tariff of 0.20 CHF/kWh it is less than 29 CHF/MWh, while at a feed-in tariff of 0.15 CHF/kWh it is above 38 CHF/MWh). Likewise, specific heat generation costs are highly sensitive to input fuel prices (e.g. if reve-

[13] The Swiss green electricity label 'naturemade' was created in 2000 by the Association for Environmentally Sound Energy (Verein für umweltgerechte Elektrizität – VUE), an independent organisation founded by a group of heterogeneous stakeholders (e.g. [23, 24], www.naturemade.ch; among others). Permission to make use of the green power label 'naturemade star' obliges the party to promote electricity from new renewables; specifically, after three years a minimum of 2.5% of the total certified renewable electricity sales must be from new renewables (e.g. wind, biomass, PV, geothermal) or so-called low-impact hydropower (i.e. hydropower that meets additional environmental criteria). Renewable electricity generated from the wood-fired CHP plant in Basel could cover this obligation for more than a third of the hydropower production of IWB [14].

[14] Based on 2004 figures, it has been estimated that depending on the wood fuel mix used (assumed maximum share of waste wood 30%), heat production costs would be between 0.004-0.017 CHF/kWh higher than if it was generated by natural gas. In other words, the higher the price of natural gas, the more it can be justified on economic grounds to use a fuel mix with a higher share of forest residues.

nues from selling electricity at fixed feed-in tariffs are disregarded, they would be around 30 CHF/MWh at a fuel price of zero, whereas they rise to as much as 90 CHF/MWh at a fuel price of 0.05 CHF/kWh).

Capital structure: The total project budget of CHF 32 million will consist of CHF 12 million of equity capital (50.1% provided by the forest owners of Northwestern Switzerland and 49.9% provided by IWB and Elektra Baselland), a credit of CHF 11.8 million offered by IWB, a capital grant from the Canton of Basel-City (via AUE) of CHF 6.5 million, and a current deficit of CHF 1.7 million (remainder). This implies that equity capital amounts to 38.1%, debt capital to 37.5%, the subsidy to 20.6%, and the current account deficit to 0.04%.

Obviously, the eventual profitability of the plant is subject to a variety of uncertainties, an important one of which is related to the actual wood fuel cost (and achievable heat and electricity tariffs/prices) and the optimisation of the on-site fuel logistics.

Finally, it should be noted that *regulatory emission limits* play an important role as a determinant of the investment and operating cost. In the case of the Basel plant, an environmental audit has to be made, since the addition of the wood-fuelled plant to the existing waste incineration plant changes the emission situation (see also section 3.6 for environmental aspects).[15]

3.3. Wood fuel supply and supply logistics

It has been estimated that, given the fuel requirements of the plant at full load, it will be necessary to supply some 4,200 m^3 of loose residue during the working week (Monday--Friday), which can be broken down to 30-40 containers of 30 m^3 loose residue per day (equivalent to a freight train with approx. nine wagons). Figure 4 depicts the difficulty of harvesting forest residue in some of the woodland surrounding the city of Basel.

[15] In Switzerland an environmental audit for wood-fired plants is only required if the planned installed capacity exceeds 100 MW.

(a) Forwarding (b) Chipping

Figure 4. Cost-effective wood fuel supply from largely steep terrain will be a great challenge.

Source: Courtesy of S. Vögtli

Wood chips will be delivered to the plant both by rail and by road transport (the political goal is to supply at least 50% by rail, even if it is considerably more expensive to do so than by road). Rail tracks and road access to the plant already exist. In November 2003 a test of the logistics provided important new insights into existing weaknesses and how to optimise the system. A particularly interesting feature of the planned logistics is the use of ACTS, a standardised roll-on/roll-off container transport turnover system (cf. Figure 5).[16] With ACTS it is possible to move the containers directly from the truck to the goods wagons (i.e. without additional lifting gear).

(a) Loading of an ACTS container in the forest (b) Wood fuel handling at plant site

Figure 5. ACTS logistics for forest residue (test run for the Basel plant undertaken in November 2003).

Sources: Courtesy of (a) S. Vögtli, (b) IWB

[16] The acronym 'ACTS' stands for 'Abroll-Container-Transport-System' (literally 'roll-off container transport system').

On-site logistics are planned as follows: a wood fuel storage and handling site will be established near the KVA site and railway access. Lorries delivering wood chips will unload their cargo directly into the silo. Containers arriving by rail will be unloaded from the wagon by a special vehicle, which empties the contents of the container into the silo. From the silo a conveyor will transport the wood chips to the dosing silo. One criterion for the required minimum on-site fuel storage capacity is that on important holidays (e.g. Christmas, Easter) no fuel deliveries need to take place. In the feasibility study, as already mentioned above, the required fuel for five days of full-load operation was stipulated to be some 4,200 m^3 of loose residue (given an hourly demand of 35 m^3 loose; [21]). Wood fuel delivery by truck would be made directly into a roofed underground silo.

The wood energy potential in the surrounding areas of Basel, including the French and German neighbouring regions, have been estimated to be around 2,000 GWh (620 GWh Northwestern Switzerland, 800 GWh Baden-Wuerttemberg, and Alsace-Lorraine around 650 GWh; [21, 25].[17] The figure for Northwestern Switzerland also encompasses a cutback of the forest resources over the next 50 years, in order to halt and eventually reduce the over-aging of the forests. This potential is considered large enough to feed a wood CHP plant of the size envisaged for Basel, which needs approximately 125 GWh. The waste wood potential in Northwestern Switzerland has been estimated to be in the order of 95 GWh [25]. Of the estimated forestry residue potential in Northwestern Switzerland of 450 GWh, less than half is currently used (206 GWh), while of the potential for wood residue from landscape conservation (51 GWh), some 9 GWh are already used. For the calculations, the price of forestry residue has been assumed to be 0.036 CHF/kWh and for wood residue from landscape conservation, 0.013 CHF/kWh [15]. Note that the optimal fuel mix to be used in the plant has yet to be determined, and can be expected to change over time (and hence also the expected fuel cost).

[17] An update of the study [25] on wood fuel potentials is planned for the second half of 2006 (funded by the IG Holzenergie Nordwestschweiz). The potential estimated by Pauli and Jocher [21] of 2,070 GWh is equivalent to about 2.6 million m^3 loose residues; the Basel plant would require about 7% of this potential (20% of the potential of the region Northwestern Switzerland). Given that there are large potentials of low-cost wood fuels available in the neighbouring regions of Southern Germany and the French Alsace-Lorraine, a certain price pressure through competing offers, especially for sawmill residues that compete against forest residues, can be expected over time. In particular, in contrast to the Basel region, sawmill residues (sawdust, wood chips, bark) are still available in significant quantities, partly from wood that has been harvested in Switzerland but is sawn in large sawmills located in Alsace and Baden-Wuerttemberg [21].

Rail transport of wood residue is only feasible over longer distances, as otherwise the cost of goods handling relative to the transport costs become too high. According to some cost estimates, combined road/rail transport to the plant from a distance of 50 km is expected to be between 30-50% more costly than road-only transport. Transport by rail is assumed to be cost competitive only if distances from the site are well beyond 100 km (on this issue see also [26], section 2.3). For political acceptance reasons, it is envisaged that transportation at distances below 100 km will also be realised by rail (goal envisaged: to transport 50-70% of the wood fuel requirements by rail). Present forestry operations will have to be adapted to the new requirements. To this end a task force has been established, whose aim is to develop a detailed concept.

3.4. Institutional set-up of the project and stakeholders involved

Figure 6 depicts the envisaged organisational structure for the planned wood-fuelled CHP plant in Basel. The main players involved are: (1) the municipal utility IWB; (2) the suppliers of wood fuel (forestry residue, wood residue from landscape conservation, waste wood); (3) additional equity investors; (4) debt capital lenders, and (5) the Canton of Basel-Stadt as the owner of the building. Additional players not depicted in Fig. 6 include (6) the Swiss Wood Energy Association (a lobbying institution); (7) waldmarketing.ch (a consultant); (8) public authorities (e.g. the Office for the Environment and Energy of Basel-City -- AUE); (9) environmental protection organisations, and (10) others.

The forest owners of Northwestern Switzerland, organised in the form of a dedicated public limited wood fuel supply company (dubbed "Raurica Waldholz AG"), hold 50.1% of the shares, while IWB holds 49.9% of the equity stock in the CHP plant. Raurica Waldholz AG is made responsible for the supply planning, logistics, and financial flows. Moreover, it will contract and bundle fuelwood supplies from additional suppliers. Global supply contracts will have a minimum duration of five years.

In the following we briefly describe the main role of each of the main players mentioned. (1) *IWB* as the operator of the plant and the seller of heat and electricity is interested in a secure and low cost fuel supply mix. IWB is part of the administrative system of the Canton of Basel-City [27]. The (2) *wood fuel suppliers* are responsible for the wood fuel supply, and will be keen to secure a reasonable long-term income for its/their shareholders/owners (hence the need to strike a balance that is a good compromise for both). (3) The Canton of Basel-City is the *owner of the building* of the KVA plant, and thus will have to rent out the real estate. (4) One or more banks will be used as possible debt capital lenders (if needed). (5) Potentially, there will be various additional *equity investors* (e.g. NGOs, private individuals). (6) *Public authorities* are the provider of subsidies, but also the responsible bodies for granting permissions and for checking that all legal obligations are fulfilled (e.g. technical and environmental standards). (7) The *Swiss Wood Energy Association*, the main lobbying institution for wood energy in Switzerland, is keen to increase the share of wood energy in the overall energy supply and at the same time very much interested to improve the image of wood energy. (8) Finally, the consultant wald-marketing.ch acts as a networker on behalf of the forest owners.

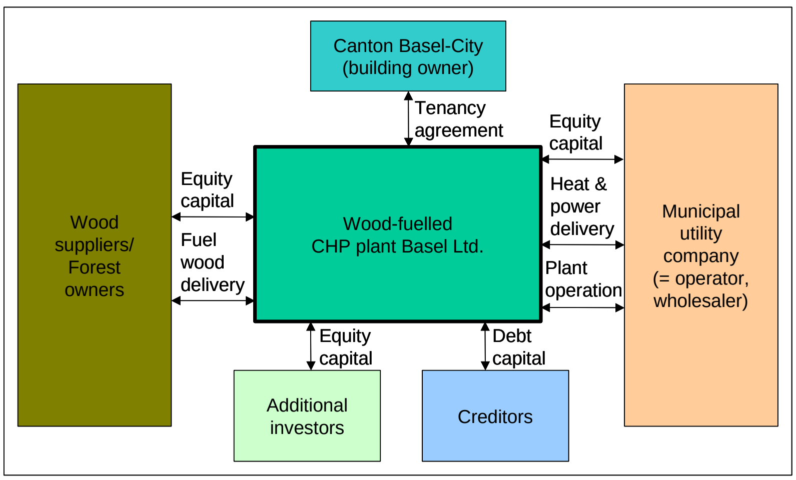

Figure 6. Proposed organisational structure for the wood-fuelled CHP plant project in Basel (simplified).

Source: S. Vögtli, adapted

3.5. Regulatory and political framework conditions

Several specific regulations are relevant when considering the construction of a large-scale biomass plant of the size planned in Basel. First, the Swiss Clean Air Ordinance imposes stringent pollutant emission limits [18]. Second, the -10% CO_2 emission reduction target stipulated in the Swiss CO_2 Act 2000 [12] puts some political pressure on the two Cantons of Basel to mitigate CO_2 emissions (burden sharing). Finally, ongoing attempts to liberalise the Swiss electricity market can be expected to have certain impacts on the viability of large-scale biomass-fired CHP plants [28].

Politically, at the national level the energy programme SwissEnergy constitutes an important vehicle for achieving energy and climate policy goals and safeguarding sustainable energy supply (for further details see e.g. [29]). In particular, it foresees a reduction in the consumption of fossil fuels by about 10% (compared to 1990), a capping of electricity demand growth at 5% (compared to 2000), an increase in the use of renewable energies in heat production by about 3,000 GWh (+3%), and an increase in the use of renewable energies in electricity production by about 500 GWh (+1%). At the cantonal level, apart from regulatory and voluntary measures, the promotion of energy efficiency, waste heat utilisation, and renewable energies constitutes the third main pillar in energy policy-making. The two cantons of Basel are among the pioneering cantons with respect to sustainable development, and a major element of sustainable development is seen in the energy domain [6, 8-10, 30]. It is also interesting to note that in the 1980s, after withdrawal from the planned (and in the mid-1970s by anti-nuclear lobbyists fiercely combated) nuclear power station Kaiseraugst, the government of Basel-City passed a law that the municipal utility must not engage in nuclear power stations.

Finally, a project-related *quality assurance system* for wood heating systems ('QS Holzheizung') has been developed for Switzerland (e.g. [31]), and has recently been expanded into a cross-national quality management system (QMS) for Austria, Germany and Switzerland ('QM Holzheizwerke'). In Switzerland this quality management system may evolve into a *de facto* standard for wood-fired plants larger than 100 kW of installed total thermal capacity, especially if the public authorities responsible for the granting of subsidies make eligibility for receiving the grants dependent on the adoption of such a QMS. For the planned wood-fired CHP plant in Basel it is expected that an independent quality management agent will be commissioned to develop a project-based quality management (PQM) system.

3.6. Environmental and socio-economic aspects

Given the size of the plant, and the many potential stakeholders involved, realisation of an urban biomass plant such as the one planned for Basel can be expected to have far-reaching environmental and socio-economic consequences. In the following we will shed some light on some of the expected impacts in terms of noise and air pollutant emissions. We will also consider employment.

In the first feasibility study three options for locating the new plant were considered. While each of the options would have caused certain environmental and socio-economic impacts, two were clearly less favourable in terms of creating additional noise and environmental risks. Road transport logistics were not at all favourable for the FKW location, as truck traffic would have to pass by the main visitor entrance, causing problems regarding space and safety requirements. Moreover, the existence of residential zones near the site implied potential restrictions due to reduced speed limits and the sensitivity of the areas to noise, pollution and the risk of road accidents. Even more problems regarding safety, noise and logistics were expected for the Werkhof location, as this site too is located near residential areas with higher transport sensitivity, and where reduced speed limits apply. In contrast, although the waste incinerator (KVA) location would induce, on average, 15% more truckloads, in the area surrounding the plant there are currently no registered noise emissions that would restrict the amount of additional noise that can be emitted from the location.

Regarding airborne emissions, the plant will have to fulfil the very stringent restrictions stipulated by the Swiss Clean Air Ordinance [18]. In particular, NO_X emissions will be kept at a minimum through circulation of the flue gas and application of the SNCR process, and are expected to be about one third below the legal limit. Fly ash will be separated by means of a multi-cyclone filter. Heavy metals and other pollutants will be reduced by injection of activated carbon and lime hydrate. The emission of fine particles (particulate matter) will be repressed by fabric filters, so that emission levels can be realised that are a factor of ten below the current legal limit of 50 mg/Nm^3.[18] Overall, the plant's emission levels are expected to be very low. Nonetheless, compared to a natural-gas-fired plant, there will be higher NO_x emissions of around 1'700 kg per annum, which will have to be traded off against the expected CO_2 emission reductions of around 30,000 t per year [15, 21].

No noise emissions measurements have been available for the KVA site, but it is planned to minimise these and to undercut the legal noise emission limits by making the building as closed as possible [15]. Additional noise emission impacts through the project will be created along the entire production chain, and will have to be balanced against benefits from climate change mitigation, reduction of fossil fuel import dependence, and others.

Employment will be created both through the construction of the plant and, more importantly, through its operation and maintenance, and through the wood fuel supply chain. It has been estimated that the number of person-years required for plant operation will be

[18] The pollutant emission limits are determined by the Environmental and Energy Administration Office (Amt für Umwelt und Energie, AUE) of the Canton of Basel-City. Other air pollutant emission limits are: 150 mg NO_x/Nm^3, 250 mg CO/Nm^3, 50 mg total carbon/Nm^3, and 30 mg ammonia/Nm^3.

eight (one person for wood chips logistics, one person for maintenance, and six persons for the 24 hour operation of the plant in shifts), and that at least some of the staff of the KVA can be deployed in running the biomass CHP plant.

Finally, on the fuel supply side, it is obvious that trade-offs exist between increasing the cost efficiency of fuelwood operations through the use of heavy machinery and extensive harvesting of wood residue from larger forest areas, and the preservation of the soil, biodiversity, and the integrity of forest areas (e.g. by minimising the number of forest access roads).

4. ANALYSIS OF DRIVING FORCES, BARRIERS, AND LESSONS LEARNED SO FAR

The main *driving forces* affecting the project seem to have been (1) the desire and perceived need of the forest owners in the Basel region to create some large-scale demand for forest residue, which is expected to greatly improve the cost effectiveness of forest maintenance operations. At the same time (2) the Basel region has been very progressive in promoting sustainable energy development, and a pioneer in the realisation of green energy projects in Switzerland (e.g. a pilot geothermal power plant that has attracted worldwide attention, a biogas plant, a 1'000 solar roofs programme, a solar power exchange). A third factor is that the municipal utility IWB is interested to sell its electricity with the green power premium label "naturemade star" which, as already mentioned above, requires that a certain amount of green power also comes from sources other than hydropower. Finally, it is expected that if the biomass-fired CHP plant is put into operation, the entire district heating grid of the city of Basel will be exempted from an anticipated CO_2 levy (an alternative candidate technology would be photovoltaics, which, however, is still much more costly per kWh generated).

Plant visits within the country and abroad apparently also seem to have played an important role, helping to reduce uncertainty and to allow for capacity building and technological spill-over. For instance, delegations of stakeholders visited plants in Meiringen, Switzerland (wood-fired CHP plant), Mannheim, Germany (large biomass CHP plant; 70 MW_{th} total thermal capacity, 20 MW_{el}, 80 t/hr steam), and Kempten, Germany (wood-fired CHP plant; 15 MW_{th} total thermal capacity, 2 MW_{el}) [21, 32]. As well as technical details the delegations were able to gather and digest much useful information, including the critical paths in the realisation of the visited plants, the investment and operating costs, the required manpower for operating the plants, how the fuel logistics can be optimised, how to convert a boiler, and where particular problems have arisen that could possibly be avoided (or at least anticipated, to allow for appropriate precautionary action to be taken).

The main *project risks* (and potential *barriers*) at the moment seem to be the following: (1) property acquisition of a wood fuel handling site; (2) future development of the waste wood market (changes in demand and supply over time and thus price development):[19] (3) political risk (up to a certain point, the project could still be killed or postponed in the course of the political decision-making process); (4) remaining uncertainty in the cost and security of the wood fuel supply and on-site logistics; (5) public opposition (people's referendum, resistance by abutters, NGOs etc.).

Several *lessons* have been learned so far:

- The profitability of the plant depends strongly on the share of waste wood to be used, currently still available at a zero price.
- Combined fuel supply by rail and road provides more flexibility, but also creates some additional uncertainty with respect to the optimal design and ultimate costs of the fuel logistics.
- Study tours played an important role in reducing uncertainty regarding technology, logistics, possible sources of operational problems, and the market structure and functioning.
- The project will only be successful if the different and in some cases opposing interests of the involved parties can be balanced (e.g. there is an obvious dilemma that the wood fuel suppliers are interested in high wood fuel prices, whereas the municipal utility would like to see low wood fuel prices). Good compromises are a prerequisite for stable and lasting partnerships, as are well-formulated long-term wood fuel supply contracts (e.g. one proposal has been to couple the wood fuel price to some natural gas price index, as a natural-gas-fired plant is the competing benchmark technology).

5. OUTLOOK—THE ROAD AHEAD

The state of affairs at the time of writing this study (September 2005) is as follows: in June 2005 the Grand Council of the Canton of Basel-City formally approved the proposal ('Ratschlag') to realise the plant. The detailed planning and tendering procedure ('Vorpro-

[19] Obviously this is only a risk to the project to the extent that waste wood is actually used.

jekt') has been initiated, and will probably last until the end of 2005. In the first half of 2006 the invitation to tender for the general contractor will be published and both the environmental audit and the issuance of the construction permit arranged. It is expected that plant construction will begin by summer 2006, and that the plant will start operating in early 2008.

Box 1. Roadmap for plant development (as of 30 Nov 2004)[20]:

Organisational

- Approval of project by management executives IWB
- Preparation of a Cantonal Council motion ("Ratschlag")
- Establishment of a Task Force (project team)
- Preparation of tenders (for planners and specialists)
- Foundation of an operating company (e.g. "Holzkraftwerk Nordwestschweiz AG")
- Development of an organisation chart (with responsibilities and competences)
- Set-up of a binding roadmap and time plan
- Property acquisition for wood fuel handling site

Financial and commercial

- Elaboration of a financial budget/scheme/plan
- Fixing of the heat and electricity price/rate
- Letter of intent/pre-contract with wood fuel suppliers (regarding price, quantity, quality, logistics)
- Definition of system boundaries and interfaces to waste incineration plant
- Preparation of the contract with the plant operator (IWB)
- Application for grants from the federal and cantonal (Basel) governments
- Validation of profitability calculations

Planning

- Development of a project-related quality management (PQM) system
- Elaboration of fuel supply logistics incl. silo storage
- Elaboration of detailed emission balances and assessment of local emission impact
- Detailed clarifications regarding power generation with existing steam turbine
- Elaboration of plans for and submission of building application
- Elaboration of an environmental compatibility audit/report ('Umweltverträglichkeitsbericht' – UVB)
- Relaunch of the 1996 project idea of a direct railway connection (negotiations with the Swiss Federal Railway Company SBB)
- Detailed technical planning (e.g. regarding fuel forwarding, steam feed-in, electrical equipment, MSR)
- Detailed planning of the air liquefaction system
- Elaboration of a measurement concept for performance control
- Tender for a general/prime contractor, preparation of the contract with the general/prime contractor
- Refinement/revision of timetable

Putting into operation

- The earliest possible date for putting the plant into operation is expected to be the end of 2006.

[20] Excerpt from [21], updated and slightly extended.

6. CONCLUSIONS

In this paper we have introduced and studied the project of a 30 MW biomass CHP plant to be set up in the city of Basel, Switzerland. The project is characterised by the interest of regional forest owners to substantially increase the demand for forest wood residue, coupled with a favourable political environment and the usability of an existing plant site that greatly helps to reduce investment and running costs. Pre-conditioned on the approval of the project in the political process, it needs to be seen whether a stable long-term equilibrium can be achieved between the interests of the forest owners and those of the plant operators. Also, the financial attractiveness under current market conditions of using waste wood has to be balanced against the loss of income for forest owners, and the green image of the plant (and the municipal utilities involved).

The following conclusions can be drawn:

1. There was a fruitful political environment for realising the plant.
2. The utility involved had a strong incentive to raise the share of renewable electricity generation, and a wood-fired plant seemed to be an economically viable and reasonably attractive option.
3. A self-activated change agent has taken on an important networking and marketing function (bundling of interests and resources, raising awareness etc.).
4. Sequential commissioning of (pre-)feasibility studies as well as field study tours to interesting plants have greatly helped to shape ideas and to mitigate risk.
5. The regional association of forest owners (WbB) has played an important role in safeguarding a reliable wood fuel supply system.

Comparing the results from the present case study with a similar one conducted for a 63 MW biomass CHP plant in the Austrian capital city of Vienna [26] reveals a number of striking parallels: (1) Use of an existing location with existing infrastructure, installations, and services (logistics, district heating grid, skilled labour force etc.). (2) Avoidance of the need to invest in important plant components, and substantial synergies with existing plant operation are expected to markedly reduce investment and operating and maintenance costs. (3) Construction of the plant on an existing site is expected to lead to much less public opposition compared to a greenfield project. (4) The municipal utilities involved are keen to realise the plant for image reasons and as part of the overall business strategy. (5) A highly motivated core group from several departments of the utilities promoted the project internally. (6) Change agents have played an important role. (7) Economic incentives (capital grants, guaranteed feed-in tariffs) are a crucial element for reducing risk and ensuring economic viability. (8) There is broad political consensus that the plants are desirable. (9) Wood fuel supply is organised long before the construction of the plant reaches completion. (10) Political will puts some pressure on the layout of the fuel supply logistics -- in favour of combined rail/truck transport, or a higher share of rail transport than would be realised on purely business economics grounds.

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