# CASE STUDY ON
# BIOCOCOMB BIOMASS GASIFICATION PROJECT
# ZELTWEG POWER STATION, AUSTRIA

**For**

**IEA BIOENERGY AGREEMENT—TASK 36**

**By**

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## BACKGROUND

Based on investigation and development of the technical concept in 1992 and 1993, and a search for project partners in 1995-96, VEG (a power station operating company of the VERBUND Group) submitted a proposal for biomass gasification/product gas combustion to the EU-THERMIE Programme in January 1996. The proposal—BioCoComb (Preparation of Biofuel for Cocombustion) was approved for funding in September 1996. Thereafter, detailed engineering was undertaken in 1996-97, and construction began in April 1997 at the Zeltweg, Austria, power plant owned and operated by Draukraft, a VERBUND subsidiary. The first cold startup occurred in October 1997, with the first hot startup occurring a month later. Commercial operation commenced in December 1997.

Generally speaking, the BioCoComb project involves partial gasification of biomass and waste fuels in a circulating fluidized bed gasifier. Produced gases and char are then fed to the existing Zeltweg conventional pulverized coal-fired boiler, where they substitute for approximately 3% of the coal feed.

Being an EU-THERMIE project, partnership is of necessity international (within the EU). The partners in this project represent five EU countries:

- **Austria**: *VERBUND Group* provided project coordination, operation of the demonstration unit, plant-related analysis; *Austrian Energy* supplied the circulating fluidized bed gasifier (design, construction, commissioning); *TU-Graz* provided scientific advice; and *ITF* provided capital funding.

- **Italy**: *ENEL* undertook gasifier characterization, thermodynamic performance testing, and modelling to optimize product gas injection point for NOx reduction.
- **Belgium**: *Electrabel* modelled the gasifier and compared results with test data.
- **Germany**: *EVS* used plant data to determine long-term effects of cocombustion on selective catalytic and non-catalytic reduction.
- **Ireland**: *ESB (LG1)* engineered the instrumentation and control equipment.

## TECHNOLOGICAL DETAILS

### Zeltweg Coal Boiler

The Zeltweg power plant (137 MWe) was commissioned in 1962. In 1982 the nearby lignite mine was closed, and the firing system was converted to utilize hard coal (tangential firing). In 1989 a selective non-catalytic reactor (SNCR) was added to handle NOx emissions, and in 1994 the Lurgi CFB desulphurization scrubber was added. Main steam data are 185 bar (high pressure) and 44 bar (reheat) at 535°C. As of 2001, the plant had operated for more than 110 000 h, in later years mainly for peak load energy production. Because of its location in Styria, surrounded by forest industry (sawmills), the plant was an ideal location for a biomass project.

### Circulating Fluidized Bed Gasifier

The gasifier is of the CFB variety, constructed of steel with internal brick and concrete refractory. The gasification chamber is a simple vertical cylinder without internal mechanical components or heat exchangers. Air enters the gasifier via an open nozzle grid (distributor) situated at the bottom of the gasification chamber. The air is preheated to about 270°C in the coal boiler recuperator. Fine sand of a defined particle size is used as the bed material. No limestone is employed as sulphur sorbent; instead, $SO_2$ is scrubbed downstream of the coal boiler. A start-up oil burner is provided for initial heat-up of the gasifier, and in the event of emergencies, e.g., a fuel feeding problem.

During gasification, feed particles partly combust in the lower part of the reactor, to produce the required temperature of 850°C; because of the lack of sufficient oxygen in the upper part, gasification occurs (partial gasification).  Variation in airflow thus controls the bed behaviour and the reaction temperature.  Particles continue to circulate in the fluidized bed system until gasification and attrition render them small enough to pass through the hot gas cyclone.  These small particles (char and ash) leave the gasifier with the gas through the hot gas duct to the coal boiler, while larger particles reenter the gasifier near the distributor where surplus oxygen is available for combustion.  Carbon burnout in the gasifier is excellent, as less than 0.40% carbon reports to the discharged bed materials.

A water-cooled screw conveyor at the bottom of the gasifier handles the discharge of bed material and any noncombustible metals, stones and mineral content.  This stream is not expected to carry significant ash, as the ash is fine and of low density, and is almost totally carried in the gas stream.  In a typical setup, the bed sand could be separated from this stream for reuse, but at Zeltweg this is unnecessary.  Sand consumption depends on the type of fuel being fired.  Bark, used almost all the time, contains sand that is suitable for bed material, and instead of dosing, discharge must be carried out intermittently, to reduce the pressure drop in the fluidized bed.  Firing of clean fuel (wood chips and sawdust) does require some sand dosing, however.

The gasifier has been designed for a thermal capacity of 10 MW, equivalent to approximately 3% load substitution in the coal boiler (344 MWth).  Hot gases an char enter the coal boiler via a specially designed burner nozzle that provides rapid ignition, a stable flame, good penetration into the coal flame, and good mixing.  The burner is situated above the existing coal burners to achieve maximum reburning effect (for NOx reduction).  See Figure 1.

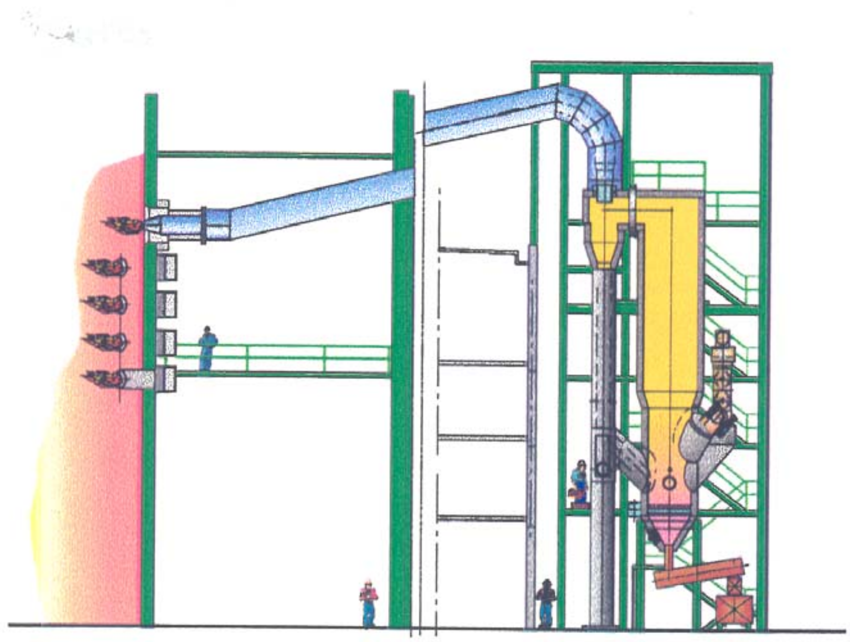

Figure 1. BioCoComb Gasifier and its connnection to the boiler

**Fuel Preparation, Handling and Feeding**

Biomass (mainly bark and wood chips) is delivered by truck to an outdoor storage pile mainly in the autumn (this is a peakload, winter-operating power plant). Supplementary fuels such as plastics, demolition wood and railway ties are generally delivered “just in time”. Wheel loaders are employed to compact the fuel. Once per day, fuel is brought to the push feeder, the beginning of the automatic handling system. The push feeder is divided into two independently controlled sections, such that blending of various fuels can be accomplished here. The push feeder has a capacity of 500 $m^3$, the daily demand for the gasifier.

Fuel travels by a series of conveyors to a 20 $m^3$ dosing silo, via magnetic separation, screening and crushing equipment. The fuel supply system has been designed on the basis that initial delivery will be mainly in the required particle size. The small proportion of oversize particles, up to 100 cm in length, is separated with a disc wheel separator. This is 3.4 m long, and consists of 16 direct drive wheels, each with 10 structural steel discs. The wheels have automatic reverse control to prevent blockage.

Particles passing the disc wheel separator are conveyed to the dosing silo, while oversize particles are delivered to the inline crusher/shredder of 20-50 $m^3$/h capacity. This unit is a one rotor crusher, 2 m in length, with automatic reverse. The rotor speed is 85 rpm, and is equipped with 108 carbide cutting tips. The cutters can be oriented in four directions for extended life. A drum screen with 50 mm diameter openings ensures that properly sized particles exit the crusher/shredder and reach the dosing silo.

The dosing silo has a push feeder discharge system that discharges feed into a dosing screw. From here, feed falls to a belt conveyor where it is weighed (belt conveyor weigher), then enters a duplex rotary feeder with a purging mechanism (to prevent gas escape at the fuel entrance, since the gasifier operates at a slight overpressure). The feeder limits particle size to 30 x 30 x 100 mm. Fuel enters the gasifier in the bed area, above the air distributor. Figure 2 illustrates flows in the BioCoComb preparation/gasification process, while Figure 3 is a photograph of the fuel preparation equipment.

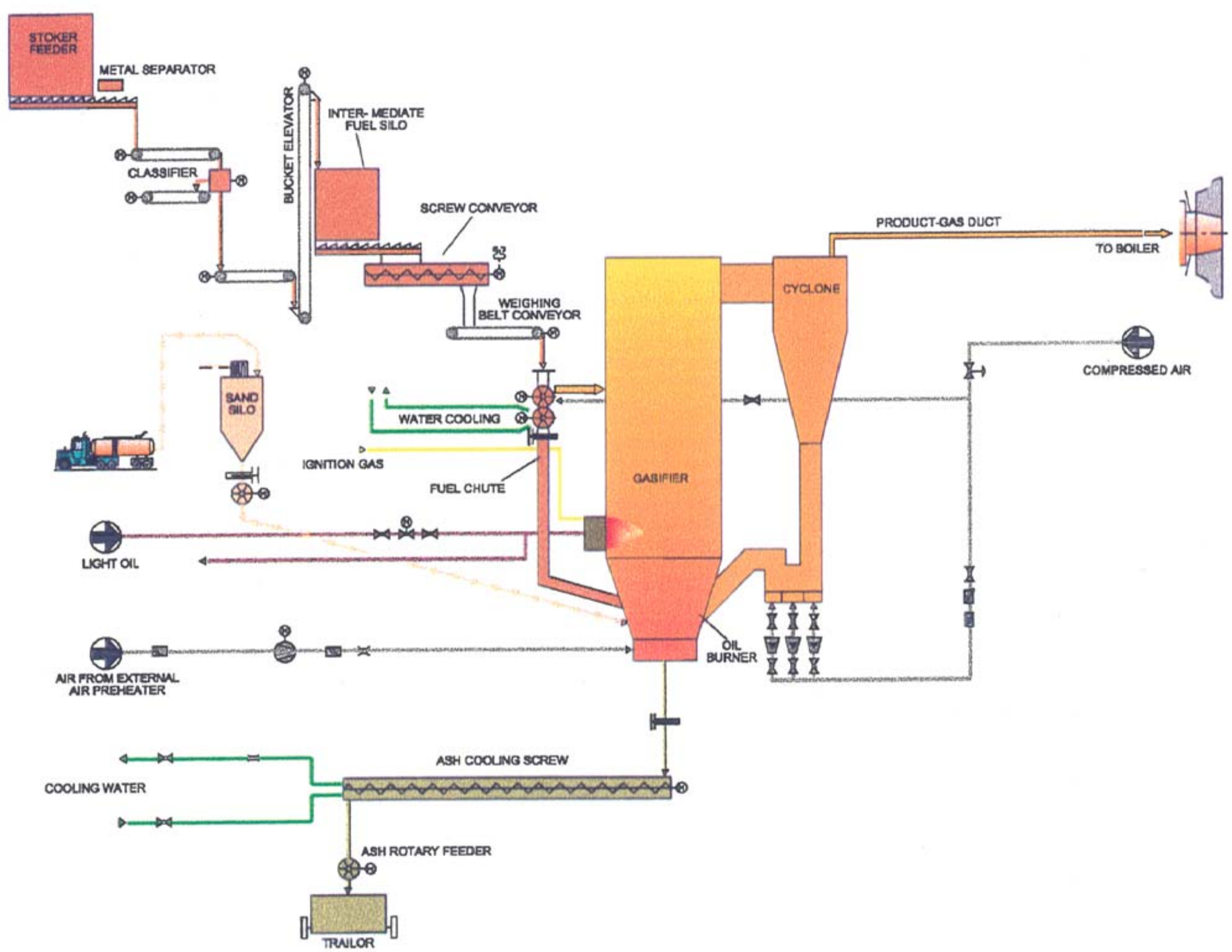


Figure 2. Flow diagram of BIOCOCOMB-process

**Figure 3. Fuel Preparation at Zeltweg Plant**

**Innovative Features of the Technology**

Although the system is designed for bark as the main fuel, market pressures demand flexibility of fuel capability (wood chips, sawdust, plastics, railroad ties, construction wood, etc.). The CFB gasifier is very flexible with respect to acceptable fuel types.

No milling or predrying of the feedstock is required. This comes about because a low-quality gas is sufficient for cofiring at this level (3%) in a stable coal flame.

The acceptability of partial gasification results in a shorter residence time leading to a smaller, less costly gasifier vessel. The fine char that passes the hot gas cyclone and enters the boiler with the gas is very similar in nature to the boiler coal feed, and is completely consumed. No energy-consuming gas filtration is undertaken.

No product gas cooling is undertaken prior to the coal boiler. This results in the maximum transfer of energy, while avoiding the possibility of hydrocarbon condensation in the ducts.

Low operating temperatures in the gasifier (about 850°C) prevent slagging. Downstream combustion in the coal boiler is at a much higher temperature, assuring maximum burnout of carbon.

Use of the product gas as a reburning fuel results in NOx reduction. This translates into an ammonia consumption decrease of 10-15% in the selective noncatalytic reactor to achieve the same NOx emission levels.

Efficiency of biomass/waste conversion to electricity is very nearly equivalent to that of the coal-fired unit. This occurs despite the increased product gas moisture content because of increased flame radiation in the furnace, and an improvement in the effectiveness of the convective heating surfaces through the back passes of the boiler and the superheater.

Finally, required modifications to the boiler envelope to accommodate the gas cofiring system are minor, consisting only of a new burner. The gasifier is connected to the boiler through the air preheater, but is 22 m away from the boiler, outside the boiler house.

**FUEL CHARACTERISTICS**

Fuels used in the gasifier--biomass as well as supplementary fuels--are purchased, with pricing based on energy content, from the surrounding area to avoid long transport distances and associated costs. Typically, fuel costs amounted to 2.5-3 EUR/$m^3$. Supplementary fuels such as railway ties, plastics, sewage sludge, construction wood waste, and electrical scrap are blended with bark and wood chips, never fired alone. These fuels, in the small quantities used, were fired under Austrian regulatory authority sanction. Table 1 presents characteristic data for separate biomass components and fuel blends.

**Table 1. Characteristic Data for Biomass and Blended Fuels at Zeltweg**

| **Component or Blend** | **Moisture (% by wt.)** | **LHV (MJ/kg)** | **Specific Weight ($kg/m^3$)** |
|---|---|---|---|
| Spruce bark | 50-60 | 6.2-8.2 | 280-380 |
| Larch wood chips | 35 | 10.9 | 300 |
| Larch sawdust | 40-50 | 8.2-10.5 | 250-320 |
| Bark, wood chips | 56 | 6.8 | 360 |
| Bark, wood chips, railway ties | 48 | 9.2 | 320 |
| Bark, wood chips, construction wood waste | 48 | 8.3 | 360 |
| Bark, wood chips, plastics (PVC-free) | 58 | 6.4 | 310 |
| Bark, wood chips, sewage sludge | 46 | 8.5 | 350 |
| Bark, wood chips, electrical scrap | 48 | 8.8 | 310 |
| Mixture of all fuels | 57 | 6.5 | 330 |

Table 2 shows a typical spruce wood chip analysis, and the calculated gas composition obtained from it. For Table 2, the reference states that 90% carbon conversion is obtained in the gasifier (partial gasification); however, as char enters the coal boiler along with the gas, the energy loss is almost totally insignificant.

**Table 2. Spruce Analysis and its Calculated Gas Composition**

| **Spruce Wood Analysis, Wt. %** | | **Calculated Gas Composition, Mole %** | |
|---|---|---|---|
| Total carbon (C) | 22.11 | Oxygen ($O_2$) | 0.00 |
| Total hydrogen (H) | 2.70 | Nitrogen ($N_2$) | 38.44 |
| Total oxygen (O) | 18.62 | Carbon monoxide (CO) | 4.55 |
| Total nitrogen (N) | 0.23 | Carbon dioxide ($CO_2$) | 12.31 |
| Total sulphur (S) | 0.00 | Methane ($CH_4$) | 0.00 |
| Ash content | 1.35 | Hydrogen ($H_2$) | 10.54 |
| Moisture ($H_2O$) | 55.00 | Moisture ($H_2O$) | 34.15 |
| | | | |
| LHV, kJ/kg wet | 6 898 | LHV, MJ/kg dry | 1.61 |

Table 3 indicates operating data for the Zeltweg station for the period 1996-1998, and indicates the amount of biomass/waste fuel blend consumed. Remember that less than two months of operation of the gasifier occurred in 1997, while none occurred in 1996. Remember also that the Zeltweg station is a peaking plant with widely varying operating patterns, depending on the weather and the resulting local electricity demand.

**Table 3. Operating Data for Zeltweg Station, 1996-1998**

| | **Units/Year** | **1996** | **1997** | **1998** |
|---|---|---|---|---|
| Operating time | h/a | 1 983 | 1 399 | 724 |
| Electricity production (gross) | GWh/a | 251.0 | 165.0 | 89.0 |
| Electricity production (net) | GWh/a | 229.0 | 151.0 | 81.0 |
| Coal used | t/a | 90 033 | 55 003 | 28 693 |
| Oil used | t/a | 417 | 254 | 492 |
| Biomass/waste used | t/a | --- | 355 | 1 939 |

Table 4 indicates total fuels gasified per type and electricity generated during the period of December 1997 to April 2001.

**Table 4. Gasifier Operating Statistics, 1997-2001**

| | |
|---|---|
| Operating period | December 1997-April 2001 |
| Total operation | 2 200 h |
| Main fuel (bark and wood chips) | 7 000 t |
| Waste wood | 1 500 t |
| Plastic waste | 50 t |
| Sewage sludge | 50 t |
| Railway ties | 200 t |
| Other fractions | 200 t |
| Electricity generation | 9 800 MWh |

## PERFORMANCE

### Environmental

With 3% thermal substitution of coal with product gas in the coal boiler, emissions from the boiler are substantially identical to those without substitution. Operating logs have indicated no increase in CO emissions when firing product gas, suggesting that gas burnout is very good. This is of special interest because the burner for product gas is atypical in that it does not have a separate supply of combustion air. Rather it is burned in the excess oxygen present in the boiler.

Because the typical feedstocks contain less sulphur than does the boiler coal, there will be a minimal reduction in overall system $SO_2$ emissions. Also, depending on the type of feedstock, there will be up to 3% reduction in reportable $CO_2$ emissions.

Of major impact, however, is the reduction in NOx emissions. This comes about as a result of the location of the gas burner in the boiler, above the coal boilers. In this "reburning" mode of operation, some of the NOx that has already formed lower down in the boiler is reduced, by a slight deficiency of oxygen, to $N_2$. The effect of this is that, to meet NOx emissions requirements set for the boiler, 10-15% less ammonia solution is required in the SNCR. This represents a 3x to 5x multiplier from the 3% product gas contribution, and should continue at this level, within limits, as the product gas substitution is increased.

### Mass and Energy Balances

As stated above, a minimal substitution of approximately 3% of coal input on a thermal basis (5-13 MWth product gas vs a total of 344 MWth entering the boiler) has almost no negative impact on the net output of 137 MWe. Because the boiler was shut down (permanently?) when the site visit took place, no operational data was available on which to base the mass/energy balance. However, the following plant data were available in the literature.

**Table 5. Zeltweg Plant Data**

<table>
<tr><th></th><th>Coal</th><th>Biofuel</th></tr>
<tr><td>Thermal input</td><td>330 MW</td><td>10 MW</td></tr>
<tr><td>Origin</td><td>Polish coal</td><td>Wood chips, bark, sawdust</td></tr>
<tr><td>Fuel consumption</td><td>47 t/h</td><td>2-4 t/h</td></tr>
<tr><td>Lower heating value</td><td>27 MJ/kg</td><td>2-5 MJ/Nm$^3$ (gas)</td></tr>
<tr><td>Internal consumption</td><td>7 kW/MWth</td><td>14 kW/MWth</td></tr>
<tr><td colspan="1">Unconverted carbon to boiler</td><td colspan="2">10 mol%</td></tr>
<tr><td>Particle size of char dust to boiler</td><td colspan="2">200 µm</td></tr>
<tr><td>Air consumption</td><td colspan="2">3.7 Nm$^3$/h</td></tr>
</table>

In addition, the following information was provided by VERBUND:

**IN:**

Biomass - 10 MWth

Coal - 330 MWth

**OUT:**

127 MWe (net to grid)

**LOSSES:**

Gasifier/product gas duct radiation - 0.124 MWth

Boiler - 203 MWth (flue gas, ash, radiation, etc.)

Internal consumption - 10 MWe

**EFFICIENCY:**

127 MWe/340 MWth = 37.4%

**Problems/Solutions**

As with most biomass/waste-fired units, operation of the Zeltweg CFB gasifier has proved to be trouble free. Inspection after the first demonstration period showed that the gasifier was in excellent condition, with no damage detectable. There were no tar deposits, and the critical hot gas duct remained clean, with no sand or fly ash sediment visible. Also, the furnace walls of the coal boiler did not show more slag deposits than when operating on coal only.

Also as with most biomass/waste-fired units, problems have surfaced in the preparation and feeding equipment. These have largely been solved, as discussed below.

The disc-wheel separator, used to separate fines from coarse feedstock, was originally fitted with asymmetric discs. Because of the resultant changing clearance between wheel and disc during rotation, larger feedstock sometimes blocked the wheels and stopped operation. Manually reversing rotation was necessary to free the blockage. Newly installed symmetrical discs, and optimization of the automatic reverse control have solved this problem.

Operation of the transverse belt conveyor caused slippage problems in low-temperature conditions when feedstock moisture content was above 50%. These were solved by reducing the angle of incline from 14 degrees to 13.5 degrees, and operating the conveyor continuously when the temperature dropped below -5°C, to keep the belt at operating temperature.

A few problems with the dosing silo have been noted and corrected. First, biomass often bridged in the silo, halting flow. Addition of baffle plates and a synthetic, slippery coating solved this problem. Second, due to wide density variations in different feedstock blends, operation of the dosing belt weigh conveyor was unsatisfactory, with gasifier input flowrate sometimes changing between 2 000 and 5 000 kg/h. This was enough in some cases to switch operation from gasification to combustion mode (when flow is below a preset lower limit). This was rectified by converting the screw before the dosing belt conveyor into a dosing screw, through internal software and control system modifications.

The feedstock rotary feeders into the gasifier were often blocked by larger particles. The control system was set to switch from gasification to combustion mode if the rotary feeders reversed more than three times in succession (when trying to clear the blockage), and this occurred several times. After a number of attempts, the problem was solved by modifying the space between discs in the disc-wheel separator, to deliver a finer particle size. However, there is still concern regarding gas-tightness of the rotary feeders. In winter, ice agglomerates have exploded upon entry to the gasifier; the resultant overpressure caused gas escape. The use of lockhoppers or some other design would be incorporated in future plants.

## CAPITAL, OPERATING AND MAINTENANCE COSTS

Total cost of the BioCoComb project was 5.1 MEUR. This amount includes engineering, biomass/waste storage, conveying system, feedstock preparation, gasifier, connection to the coal boiler, commissioning and test monitoring. Of this amount, EU THERMIE contributed 1.3 MEUR, about 25% of the total. It has been estimated that replication of the plant at the same scale (10 MWth) would cost 3.7 MEUR for preparation of the technical specifications, tenders, erection and commissioning. At 40% electrical efficiency (LHV basis), this is equivalent to a capital cost of 925 EUR/kWe, quite high due to the relatively small scale.

Several studies have been undertaken to estimate the cost of larger-scale plants. One detailed study by Austrian Energy for a 50 MWth plant is as follows:

- Plant life: 10 years
- Interest rate: 6%/a
- Power plant efficiency: 40% (LHV basis)
- Annual operation: 8 000 h

- Annual maintenance: 1.5% of investment cost
- Ash disposal cost: 75 EUR/t
- Fuel: biomass blend at 40% moisture
- Operation: 1 person per shift

The estimated investment cost was calculated as 400-500 EUR/kWe, equivalent to 9 MEUR for 20 MWe. Austrian Energy states that, from experience at Zeltweg, the power plant personnel can operate the gasification plant without additional manpower. Electricity production costs depend on the feedstock price. If feedstock is waste at zero cost, electricity can be produced for less than 0.02 EUR/kWh. This rises to 0.047 EUR/kWh if feedstock is purchased for 0.014 EUR/kWh.

A 100 MWth plant is expected to cost 10-14.5 MEUR, equivalent to a specific investment of 250-360 EUR/kWe. This shows the economics of scale. However, sufficient feedstock must be available locally to avoid high transportation costs. Also, a suitably sized boiler must be available, as a coal substitution much greater than 10-15% might adversely affect efficiency and operation of the boiler.

Averaged additional operating and maintenance costs of the complete plant to the end of 2000 were 17 EUR/h at a standard load of 10 MWth. This figure is high, but includes remedying the many system trips that occurred prior to modifications (as discussed previously). In absence of the trips, maintenance costs were near zero, including only control, cleaning and lubricating. However, this might not be representative, considering the relatively low operating hours.

**FUTURE PLANS**

Austrian Energy/VERBUND have discussed construction of a larger, commercial-scale gasifier, perhaps 50-100 MWth, for one of their power plants in Austria. To allow safe, stable operation of a larger unit, some modifications in design have been recommended. These include:

- Installation of start-up burners in a separate combustion chamber: this leads to fewer openings in the gasifier envelope, reducing the potential escape of explosive gases, and negates the need for cooling air, improving quality of the product gas.
- Installation of a separate combustion air supply (from the boiler secondary air system) at the product gas injection point into the coal boiler: this ensures complete burnout while leaving NOx reduction unchanged, and allows changeover from combustion to gasification by simply shifting the feed point of burnout air from the gasifier to the product gas nozzle at the coal boiler (and vice versa).
- Installation of variable flue gas recirculation (flue gas from the boiler directly to the gasifier windbox): this allows constant operation under instances of low oxygen demand (low load or high calorific fuels), ensuring minimum fluidization of bed materials is maintained, and simplifies the changeover from combustion to gasification, by decreasing oxygen input into the gasifier.

Unfortunately, the main boiler at Zeltweg has been shut down since April 2001, because electricity generation at the plant is too expensive (peaking plant) and there is an overcapacity in the area. However, we have been assured that gasifier operation played no part in the shutdown decision. It is, therefore, still possible that a larger gasifier will be built in conjunction with another Austrian plant, incorporating the above improvements.

## CONCLUSION

"The ready-to-use BioCoComb concept ensures the conversion of biomass to electricity at high efficiencies, but also tolerable investment and operating costs without major modifications of the present equipment." [H. Anderl and T. Zotter, AE Energietechnik]

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