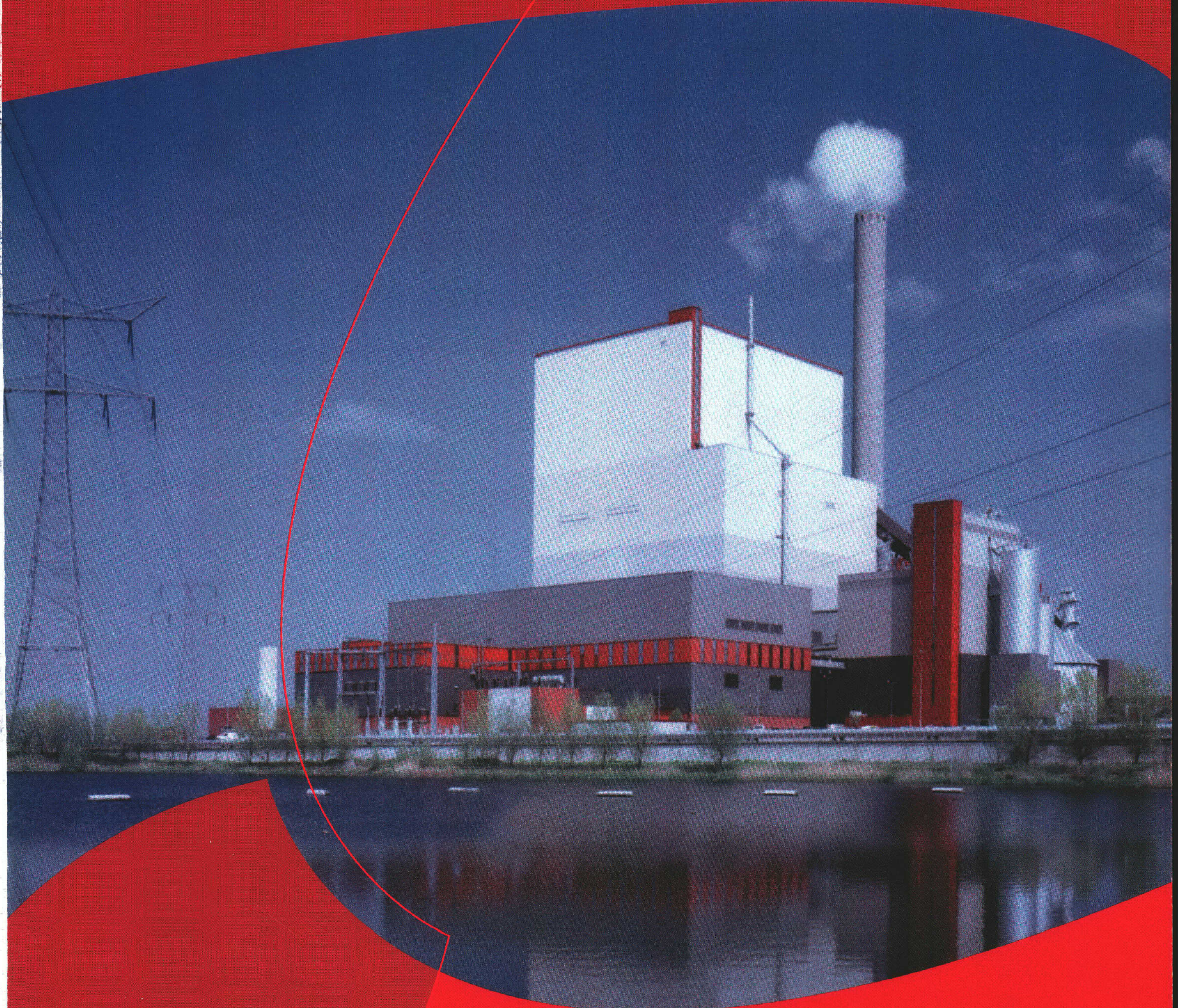
Co-combustion of gasified contaminated waste wood in a coal fired power plant

Public report to the EU



Thermie demonstration
project no. SF/323/95/NL/FI
Council decision no. 94/806/EC

essent ENERGIE

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PUBLIC REPORT to the EU

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THERMIE Demonstration Project No. SF/323/95/NL/FI

Council Decision No. 94/806/EC

Essent Energie BV
(previously NV EPZ)
Geertruidenberg,
July 20th, 2001

EU Program	: THERMIE Demonstration Program
Title of project	: Co-combustion of gasified contaminated waste wood in a coal fired power plant
EU Project number	: SF/323/95/NL/FI
EC Council decision	: 94/806/EC
Contractors to the EU	: NV PNEM (now NV Essent), The Netherlands NV EPZ (now NV Essent), The Netherlands VTT Energy Finland Browning Ferris Industries UK Ltd UK Elkraft Power Company Ltd Denmark
Project management	: dr.ir. W. Willeboer /Essent Eng.& Maintenance
Current project address and contact information	: Essent Engineering & Maintenance Project Houtvergassing P.O. Box 158 NL-4930 AD GEERTRUIDENBERG

Objectives of the Thermie Demonstration Project

- Demonstrate technical and economical feasibility of atmospheric circulating fluidized bed gasification of contaminated demolition waste wood with integrated product gas cooling and cleaning, followed by cofiring of the low calorific gas in a 600 MWe PC plant
- Demonstrate net annual reduction of 170,000 tons of CO_2 emission by substituting 70,000 tons of pulverized coal with 150,000 tons of demolition waste wood

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NOMENCLATURE

Amergas BV	Joint Venture between NV EPZ and PNEM (through its then subsidiary Energy Systems BV) -50%/50% owned by Energy Systems Zuid BV and NV EPZ (now both 100% Essent Energie BV) -lessee of Amstel Lease BV -leases and financially runs the Amer Wood Gasification plant, with operations and maintenance contracted out to NV EPZ -as of May 11th, 2001 became 100% subsidiary of Essent Energie BV
Amer Power Station (Geertruidenberg, NL)	Site of the Thermie Wood Gasification Plant project, Site owned and operated by Essent Generation, a subsidiary of Essent Energie BV Site hosts the following power plants: -Unit 9, a PC plant of 600 MWe +350 MWth CHP service -Unit 8, a PC plant of 645 MWe +250 MWth CHP service -Donge, a natl gas fired Combined Cycle plant of 120 MWe -Units 6+7, natl.gas boilers of 415 MWe (mothballed)
Amstel Lease BV	Formal owner and lessor of the Amer Wood Gasification Plant
BFI UK Ltd	Brownings Ferris Industries UK Ltd, Buckinghamshire, UK -Contractor to the EU on this Thermie project
Bowie	Bowie NV, The Netherlands -wood supplier to the Amergas BV on a long term contract basis -later on to become a subsidiary of Essent Milieu BV
Close-out date	End date of the active portion of the Thermie contract, per February 28th, 2001
Cogeneration, Combined Heat and Power	The concurrent generation of electricity and heat (CHP service)
Combined Cycle service	The generation of electricity and/or heat by gas and steam turbines in combined thermal service
Contract (to the EU)	The contract between the Contractors to the EU and the EC on the financial support to this Thermie Demonstration Project
Contractors (to the EU)	The parties underwriting the proposal and execution of the Thermie project (Managing Contractor to the EU is NV EPZ, now Essent Energie BV)
EC	European Commission, Brussels
Elkraft	Elkraft Power Company Ltd, Ballerup, Denmark -Contractor to the EU on this Thermie project

EPZ (up to May 11th, 2001)	NV Elektriciteits-Productiemaatschappij Zuid-Nederland NV EPZ, Eindhoven, The Netherlands, -a regional heat and power generation company under majority shareholder NV Essent -50% shareholder of gasification plant owner Amergas BV -operator of and maintenance provider to the Amer Wood Gasification Plant -as of May 11th, 2001 continuing to do business as a subsidiary of and under the name of Essent Energie BV
Essent	NV Essent (Holding), Arnhem, The Netherlands, -an independent multi utility company, owned by regional and local government -100% shareholder of Essent Energie BV -100% shareholder of NV PNEM - 67% shareholder of NV EPZ (up to May 11th,2001) -as of May 11th, 2001, 100% shareholder of Essent Generation and Essent Engineering & Maintenance through subsidiary Essent Energie BV
Essent Energie	Essent Energie BV, 's-Hertogenbosch, The Netherlands, -an electricity generation and distribution company -100% subsidiary of NV Essent -owner of Essent Generation (as of May 2001) -owner of Essent Engineering & Maintenance (as of May 2001)
Essent Generation	Power production department of Essent Energie BV -subsidiary of Essent Energie BV -Owner and operator of the Amer plant site -Operator of the Amer Wood Gasifier -as of May 11th, 2001 doing business under the name of Essent Generation as a continuation of EPZ Production department (and others)
Essent Engineering & Maintenance	Engineering and maintenance department of Essent Energie BV -subsidiary of Essent Energie BV -Managing Contractor to the EU on the Amer Wood Gasification Thermie project -as of May 11th, 2001 doing business under the name of Essent Engineering & Maintenance as a continuation of EPZ Techniek & Projecten (and others)
Energy Systems	Energy Systems BV -a former regional CHP generation company -a 100% subsidiary of PNEM, -former 50% shareholder of Amergas BV -became Energy Systems Zuid BV

Energy Systems Zuid	Essent Energy Systems Zuid BV -formerly Energy Systems BV -successor to Energy Systems BV in the 50% shareholding in Amergas BV
EU	European Union
Foreground Rights	Rights of EU Contractor to Foreground Information
Information / Foreground Information	All information (as specified in the Contract) as generated by any EU Contractor (or third party working for it) *in the performance of the Project*. Including all know-how which can be used for industrial and commercial applications, and relating to the Rights of Contractors and the protection thereof.
Lurgi	Lurgi Envirotherm GmbH, Frankfurt, Germany -main vendor of the gasification island of the Amer Wood Gasification Plant
Managing Contractor	The lead party among the Contractors to the EU, responsible for managing the work on the Thermie project as well as for reporting back to the EU
PNEM	NV PNEM, 's-Hertogenbosch, The Netherlands, -a former independent regional electricity supply company -Contractor to the EU on this Thermie project -currently 100% incorporated into NV Essent -100% shareholder of the (then) Energy Systems BV
Release date	Date of issue of the Final Report (confidential) to the EU, April 30th, 2001
Principal	Client for whom and in who's name the work is managed, contracted out and performed. (Principal on this Thermie project is Amergas BV)
Vendor	Contractor to the Principal (Amergas BV) or to Principal's representative (NV EPZ), delivering services and/or goods, including design, equipment, construction, start-up services or parts there of. (A total of 4 main vendor's contracted on this Thermie project)
VTT	VTT Energy, VTT, Finland -Contractor to the EU on this Thermie project

TABLE of ABBREVIATIONS

CV	Calorific Value (as used in LCV gas, or in Low CV product gas)
Dfl, Dfl's	Dutch Guilders (all budgets on this Thermie project listed in Dfl's or ECU's)
ECU	European Currency Unit, valid monetary unit at time of closure (conversion rate 1 ECU = Dfl 2,14)
EIA	Dutch: Energie Investerings Aftrek English: Energy Investment Deduction (a Dutch tax reduction mechanism)
LCV	Low Calorific Value (as used in LCV gas, or Low Calorific product gas)
OSH(A)	Occupational Safety and Health (Authority)
PC	Pulverized Coal (as in PC-fired power plant)
REB	Dutch: Regulerende Energie Belasting English: Regulating Energy Tax (a Dutch green power tax incentive)
VAMIL	Dutch: Vrije Afschrijving van Milieu Investeringen English: Depreciation of Environmental Investments over a Self-determined Depreciation Period (a Dutch tax reduction mechanism)

Summary

This project demonstrates the technical and economical feasibility of the producing and cofiring of product gas from demolition waste wood. For this purpose LCV product gas is generated in an atmospheric circulating fluidized bed (CFB) gasification plant, cooled and cleaned and transported to the boiler of a 600 MWe pulverized coal fired power plant.
Gas cooling and cleaning takes place in a waste heat boiler and a multi stage wet gas cleaning train. Steam raised in the waste heat boiler is exported to the power plant.

On an annual basis 70,000 tons of steam coal are substituted by 150,000 tons of contaminated demolition waste wood (50,000 tons oil equivalent), resulting in a net CO2 emission reduction of 170,000 tons per year, while concurrently generating 205 GWh of electrical power.

The wood gasification plant was built by NV EPZ (now incorporated in Essent Energie BV) for Amergas BV, now a 100 % subsidiary of Essent Energie BV.
The gasification plant is located at the Amer Power Station of NV EPZ Production (now Essent Generation) at Geertruidenberg, The Netherlands.

Demonstrating several important design features in wood gasification, the plant started hot service in the Spring of 2000, with first gasification accomplished in the Summer of 2000 and is currently being optimized.

As per early June, 2001, the milestone of 500 hours of gasification was reached.

1. Introduction

Status of this Public Report

This Public Report covers the work, the objectives and the results of this Thermie demonstration project and is issued for publication by the Community and the Contractors to enable third parties in the EU and its associated states to become aware of opportunities to request a license for the gasification technology developed in this project with the help of EU funding.

General information

During October 1998 construction of the biomass gasification plant was started at the Amer Power Station at Geertruidenberg, The Netherlands.

Designed as an atmospheric circulating fluidized bed unit (ACFB), the plant is licensed for the gasification of contaminated demolition waste wood, while the technology applied is suited for a wide variety of types and qualities of biomass and wastes.

Site construction of the plant was completed during the Spring of 2000, followed by hot commissioning. Commercial operations are scheduled for late 2001.

The gasification plant is formally owned by Amergas BV, a joint venture company equally owned by NV EPZ and Energy Systems Zuid BV, both partners in the mean time owned by Essent Energie BV, 's-Hertogenbosch, The Netherlands.
The wood fuel supply was secured by a long term contract.

The coal fired power plant, Amer Power Station Unit 9, cofiring the product gas, is owned and operated by NV EPZ (now Essent Generation). This unit was commissioned in 1993 and operates in CHP service, delivering 600 MWe of electrical power as well as to 350 MWth of district heating.

Positioning and economics of the project

Wood gasification has both environmental and economical advantages. Gasified wood replaces part of the steam coal in the main plant, resulting in a considerable reduction of CO_2 emission. Thus, the gasification project is well positioned in the Dutch and European governmental strategies to promote the generation of sustainable power.

Generally speaking, the economics of wood gasification are still marginal. Therefore, a variety of financial instruments had to be adopted to close finances on this project, leaving a substantial business risk to the plant owners.
More specifically, plant economics were balanced through the use of a fuel price advantage (i.e. demolition wood over coal), by a Dutch "Regulating Energy Tax" waiver (REB, on qualifying sustainably generated kilowatt-hours), and with the help of the Dutch fiscal stimulation tools VAMIL and EIA (both accelerated depreciation programs).

On the investment side, financial support was provided by the European Union through the Thermie program and the Dutch government through the national "CO_2 Reductieplan".

Total investment cost of the Amer Wood Gasification Plant is projected to reach 90 million Dutch Guilders. The public and environmental benefits can be considered as substantial.

Innovative parts of the project

The particularly innovative parts of the project can be listed as follows:

- *gasification of contaminated wood as a large scale continuous process*
  -large scale gasification of clean wood residues is practiced commercially already, however, large scale gasifiers on demolition waste wood are not yet in operation
- *product gas cleaning before cofiring in the main boiler*
  -cleaning is required to uphold the high quality of the coal fly ash,
  -allows for operations within the stringent licensing permit of the main power plant,
  -helps to meet the main boiler manufacturer's quality requirements for wood gas, in order to uphold the efficiency and life expectancy of the boiler superheater section
- *integrated operation of a large scale circulating fluidized bed plant*

-operations including integrated wet gas cleaning

- *cofiring of Low CV product gas in a large base load utility power plant*
  -including meeting the high reliability and availability requirements of the main plant with regard to grid delivery, load following, start/stop operations and long term financial feasibility

The overall lay-out of the gasification plant is made up of proven individual components. However, these components have been mostly proven in *other services* and/or with *other fuels*. Hence, this project is new and unique with respect to the integration of proven equipment components into new systems in new services.

Risks and opportunities

An innovative project as the Amer Wood Gasification Project is open to technical and operational risks.

Technical risks are associated with the first of a kind nature of the project and center around gasification, product gas cooling/cleaning and cofiring of LCV gas in a PC boiler.
No proven technology on either of these subjects is available, neither are adequate availability statistics.

Operational risks are associated with the availability of the gasifier plant, the availability of the main power plant (impacted by cofiring), the long term wood fuel supply and price stability, and the long term stability of the "green" tax waivers and incentives as set by the national government and the EU.

With respect to the different types of uncertainties the following can be noted:

- on uncertainty about the *long term fuel supply*:

-although a long term contract has been closed for the full amount of fuel for the plant, some uncertainty remains due to the still strongly developing wood fuel market

- on uncertainty about the *development of wood fuel prices*:

-this is directly related to the ongoing turbulence in the biofuels fuels markets

- on uncertainty about the level and duration of the *fiscal incentive schemes*:

-this is crucial to the economical viability of the project. In the feasibility studies based on the current situation, almost half of the operational costs are to be covered by the regulatory energy tax waiver (REB), introduced to stimulate sustainable power. However, it is unknown if this waiver will stay unchanged over the next 5, 10 or even 15 years

- on uncertainty about the value of the *"green labels"*:
  -the system of labels to be earned on the generation of sustainable power is only in it's development stage and needs to be proven on an EU scale.

Next to the project risks there will be clear business opportunities for the partners in Amergas BV. These business opportunities include the chance to acquire a leadership position in biomass conversion in The Netherlands and become a low-cost producer of sustainable electricity. Such opportunities were an important motive for NV EPZ and Essent Energy Systems Zuid BV (and their mutual parent at the time NV PNEM, now NV Essent) to enter this project.

The waste wood fuel market

In The Netherlands, disposal of combustible wastes has been forbidden by law. This law was introduced sequentially for different types of wastes, including demolition waste wood.

Approximately one million tons of demolition waste wood is currently generated annually. A substantial portion of this waste wood is paint free, as well as free of glue and other contaminants. This so called "A-quality" waste wood is primarily rerouted to the chipboard industry.
Another -but relatively small- portion of the annual demolition wood supply is impregnated waste wood, known as "C-quality" wood.
The remaining bulk of approx. 350,000 to 500,000 tons per year is lightly contaminated but not impregnated. It is rated "B-quality" waste wood.

Nominal capacity of the Amergas project was set at 150,000 tons per year of "B-quality" wood, covering approx. 30-40% of that market segment in The Netherlands. Chemical contaminants in "B-quality" wood do not pose a problem to the Amergas gasifier due to the integrated multi-stage gas cleaning system.

After exhaustive market studies, a single long term contract was closed with a single wood supplier, covering the full annual requirement of chipped waste wood. In order to guarantee continuity of supply, this fuel contract stipulates the wood supplier to create and maintain a strategic reserve of a minimum of 75.000 tons of wood, approximately half of the annual fuel requirement of the plant.

2. Project Objectives and Plant Design

2.1 Project Objectives

The project objectives have been to:

- attain *high energy efficiency* of the gasification plant in order to realize a high CO_2 emission reduction at the given equivalent power level
- enable *high fuel flexibility* of the gasification plant to accommodate the expected widely diverging (bio)fuel qualities in the future
- allow *minimal or no impact on the operational flexibility of the main power plant,* including dynamic response, power capacity, plant availability and reliability, boiler superheater scaling and fouling
- maintain *existing levels of air emissions* of the main power plant
(no negative quality impact to be allowed)
- maintain *existing auxiliary product quality* of the main power plant
(no negative quality impact on residual products to be allowed)

2.2 Plant Design

Process selection
Direct injection of fairly *clean* waste wood powder in a coal fired power plant is a viable and demonstrated process. A good example of cofiring of powdered wood can be found at the PC power plant Gelderland 13 of Electrabel Benelux, at Nijmegen, The Netherlands.
Direct injection of *contaminated waste wood* (like demolition waste wood as used in this project) will most likely negatively impact the quality of the coal fly ash.

This project was not allowed to impact the certified coal fly ash of the main power plant Amer 9 due to the importance of being able to continue the disposal of coal fly ash as commercial grade building material.
Therefore, adhering to the objectives, it was decided early on to permanently and fully separate the wood fly ash stream (with possibly some contaminates collected) from the coal fly ash stream.

A second selection criterion involved the minimization of NOx emission of the main plant during cofiring conditions. Stringent licensing permit levels imposed on the main plant do not allow for additional NOx emissions to be potentially contributed by cofiring. Thus, the gasification process was to eliminate nitrogen based gaseous components.

As the third selection criterion, high overall conversion efficiency and minimal impact on the operational characteristics of the main plant were evaluated.

A fourth selection criterion involved the potential for future system scale-up and fuel flexibility of the conversion process.

The selected process

To satisfy all these criteria the Contractors selected Atmospheric Circulating Fluidized Bed gasification (A-CFB) as the preferred technology to be applied, including full independent wood fly ash filtering and wet wood gas scrubbing.

Chipped demolition waste wood (slightly contaminated by paints) is gasified, after which the resulting product gas is subsequently cooled down, filtered for wood fly ash in baghouse filters, wet scrubbed for ammonia, reheated, and finally exported to the PC-boiler for cofiring.
This way, an annual total of 70,000 tons of steam coal is replaced by 150,000 tons of wood chips, resulting in a net CO_2 emission reduction of 170,000 tons/year.

Wood-based (design) efficiency of the gasification and cofiring process is 34% in the simple cycle electricity generating mode (at 29 MW-electric).
In CHP mode of the main plant -delivering both district heat and power- the wood based design efficiency reaches up to 50%.
The wood-based emissions (SO_2, NO_x, halogens, heavy metals) are very low, and well below those of any competitive conversion technology.

Receival, storage and fuel feed

Chipped demolition wood is transported to the plant by truck. Trucks tip into a receiving pit from where the chips are transported by walking floor, conveyer belt and elevator to the main storage silo while passing a weighing belt. This main storage silo has a volume of 10.000 m^3, equivalent to 4 days of fuel consumption at full load.
From the main storage silo the chips are transported by conveyor belt to an intermediate storage silo located in the gasifier structure just above the gasifier. From the intermediate storage silo a screw feeder feeds wood chips to the rotary locking valve feeding into the gasifier vessel.

Gasification conditions

The gasifier is of the atmospheric circulating fluidized bed type and uses ambient air as the gasification agent. The process operates at a slight overpressure of 0.2 - 0.5 bar gauge and at a gasification temperature of 850 - 950 °C. The bed material consists of sand and limestone or dolomite as required.
After passing a cyclone the raw product gas is fed to the gas cooler.
The product gas is to be cleaned from (contaminated) wood fly ash and ammonia first, before being exported to the main power plant.

Gas cooling

In order to be able to filter the gas for fly ash in baghouse filters, it needs to be cooled down to a temperature of 200 - 240°C in a gas cooler. In this gas cooler -operating as a waste heat boiler- slightly superheated intermediate pressure steam is raised to help reach a high overall conversion efficiency of the gasifier plant.
The IP steam is exported to the main power plant for electrical power generation and district heating.

Gas filtering

After cooling the gas is cleaned in a set of 4 parallel arranged baghouse filters to a clean gas specification of < 10 mg/m^3 of dust. The filtered out fly ash is stored in a silo. From this silo the fly ash is transported by truck to the building materials industry to be used as a raw material.
Part of the fly ash is recycled to the gasifier in order to improve the gasification efficiency as well as improve the flow characteristics of the fly ash.

Gas scrubbing

After dust filtering the product gas is saturated with water in a quench vessel and scrubbed in a wet scrubbing vessel to a temperature of 35°C. In the wet scrubber ammonia is washed out and dissolved in water.
After scrubbing, the product gas is free of ammonia, resulting in a minimum formation of NOx from product gas during cofiring. A minimum NOx contribution has been a design objective of the project to help assure a zero NOx emission increase of the main plant.

Gas reheating

After scrubbing the product gas is reheated by steam to approximately 100°C before being exported to the main plant through a singular, insulated, overhead, pipe line.

Gas cofiring

The cleaned and reheated product gas is cofired in 4 dedicated wood gas burners located at the four corners of the main suspension boiler at the lowest burner level.

Ammonia and waste water disposal

The scrubber waste water is stripped of ammonia, after which the cleansed scrubbing water is recycled into the circulation system of the scrubber. The gaseous ammonia is recycled and burned in the gasifier.
Since there is an excess of waste water, a continuous waste water bleed stream is exported to the main plant, where the water is injected into the boiler and evaporated.

Maintaining original emissions levels

Contaminants in the waste water as evaporated in the main boiler, are similar to those which would otherwise be derived from the now substituted coal (although somewhat less on a thermally equivalent basis). Consequently, the flue gas treatment system of the main plant is able to maintain the original low overall emission level of the main power plant.

Energy performance data

- capacity: 29 MW-electric in simple cycle electricity generation mode
  or 26 MW-electric + 15 MW-thermal in CHP mode

- wood-based conversion efficiency: 34 % (net) in simple cycle elec-generation mode
  or 31 % elec + 18 % heat in CHP mode

Environmental data

- CO2 emission reduction of 170,000 tons/year compared with 100% coal firing
- emissions lower than power station licensing permit and stringent Dutch waste incinerator regulations
- residual products, including bottom ash and fly ash: 7,000 tons/year
- no (net) waste water production
- no external ammonia release

Flow Schematics

Flow schematics providing an overview of the gasification plant with fuel unloading and storage, gas cooling, wet gas cleaning, waste water processing, and integration with the main power plant, are presented in the back of this report.

Provided are:

- -a "Schematic process diagram wood gasification" (Figure 1),
- -an "Energy balance of main power plant Amer 9 with gasifier" (Figure 2), and
- -an "Overview of the Amergas biomass gasification plant, together with the power plant Amer 9" (Figure 3).

3. Management and Organization

3.1 Participating Thermie Contractors to the EU

Company description

The following companies are Contractors to the EU under this Thermie program:

- **NV PNEM**, 's-Hertogenbosch, The Netherlands
  a large supply & distribution company of electricity and gas in The Netherlands, later to become incorporated in NV Essent
- **NV Elektriciteits-Productiemaatschappij Zuid-Nederland EPZ**
  an electricity generating utility in The Netherlands, owner of the Amer power station in Geertruidenberg and the main power plant involved, unit Amer 9,
  recently incorporated in Essent Energie BV
- **Brownings Ferris Industries** (BFI) UK Ltd, Buckinghamshire, UK
  a large waste and biomass collection and disposal company
- **Elkraft Power Company** Ltd, Ballerup, Denmark
  a Danish generator of heat and power with substantial activities in the field of co-combustion of biomass
- **VTT Energy,** VTT, Finland
  the Technical Research Centre of Finland

3.2 Project Management and Organization

Project management

The project manager had several designated technical project teams perform basic design, procurement, detailed design, commissioning, start-up and initial operations. These technical teams were complemented by designated procurement specialists, accounting personnel and secretarial staff.

Fuel procurement

A separate team was created to study the waste wood fuel market. This team oversaw the long term fuel procurement process, eventually resulting in a single long term fuel contract with a single supplier.

Conceptual design

Overall plant design was based on a conceptual design by Essent Engineering & Maintenance (previously EPZ Techniek & Projecten).
For management purposes the project engineering scope was subdivided into 4 equipment systems packages, for:

- wood gasification, gas cooling and wet gas cleaning (Lot I)
- fuel receiving, transport and storage facilities (Lot II)
- product gas burner system connected to the main boiler (Lot III)
- modifications and extensions to the boiler control system of the main plant (Lot IV)

Turn key procurement
For each of the packages a turn-key order was issued, covering detailed design, construction, start-up and commissioning:

- fuel receiving, transport and storage facilities: Heijmans/Raumaster
- gasification plant with gas cooling and cleaning: Lurgi GmbH (main vendor)
- wood gas burner system: Schelde Engineers & Contractors
- modifications to the boiler control system: Siemens

Start-up and Commissioning
For start-up and commissioning a dedicated allround team was created, including personnel from the project design office, vendors and Amer9 power plant operations.

Performance Monitoring and Dissemination of information
Performance monitoring services are provided by BFI of the United Kingdom and Essent Energie BV of The Netherlands (previously EPZ), assisted by VTT of Finland.

Dissemination of information services will be supported by Essent Energie BV of The Netherlands (previously EPZ), complemented by VTT of Finland, BFI of the United Kingdom and Elkraft of Denmark if so desired.

3.3 Plant ownership and operations

Joint Venture Model
Due to the specific risk profile of the wood gasification and cofiring concept the decision was made to arrange ownership of the gasification plant in a separate joint venture company. This joint venture company, Amergas BV, was founded by NV EPZ and Energy Systems Zuid BV (now both owned by Essent Energie BV) on an equally shared basis.

Amergas BV was legally founded in December 1998 and is the responsible legal entity for financial plant operations. The actual daily field work (including control room operations and maintenance) is performed by Essent Generation and Essent Engineering & Maintenance personnel on a service contract basis.

Risk sharing Model
Through the joint venture model of Amergas BV, risks and opportunities of the project are equally shared by NV EPZ and Energy Systems Zuid BV (a Essent Energie BV subsidiary).

As of May 11th, 2001, also NV EPZ has become fully incorporated in Essent Energie BV, thereby now repositioning Amergas BV as a 100% subsidiary of Essent Energie BV.

4. Project Development

4.1 Project Schedule

Project schedule

Phase		1997	1998	1999	2000	2001
1	**Design**	xxxxxxxxxxxx	xxxxxxxxxxxx			
2	**Equipment Manufacturing**		---------xxxxxx	xxxxxx---------		
3	**Site Construction**		---------xxxxxx	xxxxxxxxxxx--		
4	**Commissioning** of Thermie gasifier and cofiring systems			----------------x	xxxxxxxx------	
	Commissioning of additional gas cooling and cleaning systems				-----------xxxx	xxxxxx--------
5	**Final commercial acceptance run**					-----------TT--

Gas cooling and cleaning commissioning is continuing for an additional 6 months after the formal completion date of the Thermie project as per February 28th, 2001.

Debottlenecking activities are scheduled for completion during the 3rd quarter of 2001 followed by a trial run and acceptance run.

Commercial operations are to start immediately after.

4.2 Project Budget

Final project budget
The final project budget was set at Dfl 90 million.

Budget support by the Dutch Government
The CO2-Reduction Office of the Dutch government provided a grant of Dfl 13.0 million Dutch Guilders.

Budget support by the Thermie program
Internal man-hours spent by staff of the proposing Contractors were *not* included in the budget proposal to the EU and were to be carried by the individual Contractors, as were the general overhead costs.

THERMIE PROJECT SUPPORT in million Dfl's (excl VAT)

Phase	Activity	EU granted
1	Design	1.56
2	Manufacturing	9.15
3	Site construction	0.06
4	Commissioning	0.09
5	Monitoring & Dissemination	0.24
	total in Dfl	11.10

4.2 Project Execution

Summary of milestone data

- First Purchase Orders issued -first half of 1998.
- Site Construction -October 1998 through early 2000.
- Functional Dry Testing -started Nov 1999
- Hot Commissioning -started Spring 2000
- First wood combusted -April 2000
- First gasification -August 2000
- Commercial operations at full capacity -scheduled for late 2001.

Modifications
Several major modifications to the project scope were adopted during project development:
- increase of the wood chips fuel capacity from 100,000 to 150,000 tons/year
- modification of the fuel delivery concept from 50/50% by barge+truck to 100% by truck
- addition of wet product gas cleaning (wet ammonia scrubbing)
- reduction of the number of gasifier fuel feeding systems from 2 to 1

Execution
Project execution started in early 1997 after the Dutch government agreed to subsidize the project in addition to the support already granted under the Thermie program.
An Environmental Impact Statement report was prepared and permit procedures were started up. The situation on the waste wood market was evaluated and a base for long term fuels contracting developed.

Early 1998 the licensing permits were received, without any objections from the side of the general public, a clear indication that the project had full acceptance from both authorities and general public. This lack of objections could be attributed to the excellent emission figures presented: very low air emissions as well as no appreciable waste water discharge.

All necessary contracts were signed during 1998.
The long term wood supply contract was awarded to BOWIE of The Netherlands, a company with broad experience in the recycling market.
Contracts for equipment design, supply and commissioning were awarded to Lurgi, Royal Schelde, Siemens and Heijmans (with Raumaster as its subsupplier).

- the contract for the main gasifier plant was awarded to Lurgi.
- the contract for the wood gas burners and modification to the boiler of Amer Unit 9 was awarded to Royal Schelde in July 1998.
- the contract for the logistic systems, including truck unloading facilities, storage silo and conveyor systems, was awarded to Heijmans in October 1998.
- the contract for the modification of the boiler control system of the main power plant was awarded to Siemens in December 1998.

Basic design of the plant was completed in December 1998, followed by detailed engineering and the start of equipment manufacturing of the key components during the first half of 1999.

In the mean time, site construction had started with civil foundations laid in October 1998.

During May and June of 1999, erection of the steel structure was completed and most of the big equipment lifted into place in the structure.

During the second half of 1999, heavy equipment installation was almost finished, with most of the remaining work in the area's of interconnecting piping, installation of the wood gas burners, installation of cabling and instrumentation, piping and equipment insulation and finishing up of the civil work.
The fuel logistics systems (receival building, intermediate transport systems and storage silo) were completed.
Commissioning activities started.

By now the commissioning sequence showed that the complexity of the plant -as well as its first of a kind nature- required a more modest pace of commissioning than with plants of proven technology. This conclusion was reached in spite of the considerable know how in gasification technology brought to the project by both the main vendor and NV EPZ.
Consequently, for the remaining debottlenecking activities more time had to be allotted than originally scheduled by the main vendor.

Early in 2000, as site construction activities came to a close, functional dry testing -cold commissioning- started directly followed by hot commissioning.
On July 1, 2000, commissioning of the following systems were finished:

- utilities and air compressor systems
- heating-up burners on natural gas
- gas cooler steam systems
- fly ash filters
- gas saturator
- gas reheat system
- fuel logistics systems, including receival building, storage and transport
- gasifier wood and bed material feeding systems
- testing of control systems on systems and full plant scale
- technical and organizational safety provisions

as well as:

- bringing the gasification system up to full operational temperature
- operating the gasifier on wood in the combustion mode
- feeding product gas to the wood gas burners and operating in the combustion mode

During the second half of 2000 cold commissioning was complete.
Now the first gasification runs started.
First results indicated that the fuel logistics and actual gasification in the gasifier vessel worked satisfactorily.
Cofiring of the wood gas in the main boiler turned out quite successful.
Hot systems commissioning continued with:

- commissioning in the combustion mode of the plant (combustion of wood), including flue gas cooling, flue gas saturation and reheat
- while shifting to commissioning in the gasification-mode:

commissioning of the wood gas burners in the boiler of the main power plant

- testing and improving the controls system for those system parts already commissioned

Successful hot commissioning was in progress when it was decided that the gas cooler (waste heat boiler) required modifications due to fouling experienced in the gasification runs. Changes were made in the hardware design of the gas cooler, the filter cones and the gas reheater, but the functional specifications and associated process conditions of the hardware remained unchanged.

5. Operational Results

5.1 Hot Commissioning

Hot Commissioning

Hot commissioning of the plant started during Spring 2000 with preheating of the gasifier on natural gas and commissioning the steam boiler and gas relief systems with auxiliaries (air, nitrogen etc.).
During this phase, unstable operations of the natural gas fired start-up burner of the gasifier vessel were observed. Operation of the start-up burner was getting distorted by the circulating fluïdized bed. Burner modifications and optimization of process conditions were required to solve this problem.
As soon as the gasifier reached nominal operating temperature, "hot spots" appeared on the outer skin of the gasifier vessel, indicating structural damage to the refractory lining. Repair of the refractory took two weeks, including extra time for temporary restrictions on the rate of temperature increase of the newly repaired lining.

In the next phase wood fuel was fed to the plant. This phase included the commissioning of all solids handling systems (wood and sand supply and intermediate storage), wood and sand feed to the gasifier, bottom ash and fly ash discharge systems. The systems are equipped with a number of rotary star valves, sensitive to larger "foreign metal objects" in the wood fuel. Optimization of the metal removal process during fuel prep at the wood supplier's was necessary.
Also, the bottom ash discharge and recycle systems was modified

At first, from April 2000 on, the gasifier was operated on wood in the combustion mode only. In this phase the wet gas cleaning, oil separation of the stripping water and waste water cleaning systems were still bypassed.
Then, from August 2000 onwards, the gasifier was also operated in the gasification mode, with the product gas cofired in the main boiler in parallel.
After several gasification runs the fuel logistics and gasification system operated satisfactorily. However, the gas cooling and cleaning systems required additional attention.

5.2 Operational Results and Current Status

Relevant operational results can be reported:

- the gasification process is running very stable: the circulating fluidized bed is controlled well and the wood feed to the gasifier can be adjusted very accurately, allowing for good control of the fuel/air ratio;
- the conversion process is started up in the combustion mode in order to preheat the plant; transition from the combustion to the gasification mode -a critical action- has been passed several times with good results;
- combustion of the product gas of the gasifier in the main boiler proved to be successful from the start. Even though ammonia removal in the gas cleaning section was not in operation, NO_x production of the main boiler did not show an increase after wood gas was fired in the boiler;

- steam raised in the gas cooler was successfully fed into the steam system of the main power plant;
- truck fuel unloading runs well, with little dust emissions. The main wood chips storage silo (10.000 m^3) was taken into operation and filled up carefully, in order to test the reclaiming system step by step while increasing the storage level. The silo with reclaiming system works very well for the available fuel, i.e. chips from shredded demolition wood.
- after modifications the gas cooler showed relatively stable operations for gas temperatures down to approx. 380 C. Temporary after cooling from 380 to 220 C was provided by water spray injection.

Status as of February 28th, 2001 (per close-out date of the Thermie project)

- Hot commissioning of the gasification plant was completed. The process shows stable operation of the complete plant with exception of parts of the wet scrubbing section.
- Cofiring of the product gas in the boiler of the main plant showed good results on the wood chips gasified, even without the gas cleaning system fully in service.
- Debottlenecking of the cooling and cleaning section of the gasification plant continued in order to:
  - -bring the capacity of the plant up to full load
  - -improve the availability
  - -test and include the operational flow scheme under varying process conditions

Status as of April 30th, 2001

- The gasification plant load was up to 60% of full load, steadily increasing.
- Attention was being paid to lowering the air/fuel ratio's.
- Use of coal fly ash as bed material was being optimized.

5.3 Problems encountered

Early in the year 2000, commissioning progress came under pressure off and on for several reasons:

- overpressure occurred in the steam system due to human error. As a consequence, additional equipment checks and extra steam drum inspection was required, absorbing one full week of commissioning time

- start-up and stable operation of the natural gas start-up burner of the gasifier gave cause for concern and at first was hardly possible at all. Intensive trouble shooting revealed that the problem was to be found in the fluidized sand bed in which the start-up burner extended its flame. When this bed was too dense, the stability of the gas flame was distorted. Also, burner design showed inherent poor Lambda robustness. A solution was found in temporarily lowering the density of the bed during start-up, up to the point where the density was just high enough to still secure an uniform temperature distribution in the gasifier.

- damage to the refractory of the gasifier forced a stop of the plant on 4 independent occasions. The gasifier consists of the gasifier vessel proper, a cyclone, a solids return leg as well as a swan neck section through which solids return to the gasifier. This closed loop system is fully lined with refractory and has an uninsulated outer steel hull.

Due to the thickness of the refractory cooling down and reheating of the plant takes a total of one week, so that even a small repair required a lot of commissioning time. Apart from some quality assurance problems, the underlying cause for continued damage to the refractory appeared to stem from low frequency pressure oscillations in the circulating bed material flow, causing the gasifier vessel to actually shake with subsequent detrimental effect on the refractory (attached to the relative flexible steel outer shell). This effect was especially noticeable in the area of the structurally complicated goose neck at the re-entry point of the circulating bed material into the gasifier. The goose neck was constrained to suppress further swinging and was locally reinforced to eliminate unwanted flexibility of the outer steel hull. Also, the anchoring of the refractory was improved in some places.

- problems occurred in the bottom ash discharge system of the gasifier. The most critical parts in this area are the rotary star discharge valves, having only minimal tolerances. The gasifier fuel being derived from demolition wood, contains metal scrap particles to some degree. This metal scrap (if and when present) causes immediate blocking of the rotary star valves.

Operations of the bottom ash system was optimized and the wood quality improved. First, metal scrap was temporarily removed from the wood by metal detector and manual searching. Later, metal removal at the wood supplier's chipping plant was structurally improved to avoid any further problems in the feeding system.

- the Instrumentation, Control & Automation system became increasingly complex, much more so than originally anticipated by vendor

Commissioning of the instrument & controls system of the plant showed that programming of the automatic controls needed improvement. It became apparent that a number of programs for systems and subsystems could only be finalized after test work under actual operations conditions. The lack of an established experience record became clearly noticeable here.

Although a variety of problems occurred during commissioning, none were of a fundamental nature or directly related to the basic gasification process. Hence, performance expectations of the plant for the post-commissioning period were basically unchanged.

Later in 2000, commissioning slowed when the following problems requested attention:

- Again metal scrap in the wood. Demolition wood chips were made by the wood supplier in a chipping plant containing (no less than) 3 magnetic separators and 1 non-Ferro one. Notwithstanding the separators, a substantial quantity of larger metal scrap was still being found. The scrap continued causing problems in the gasifier fuel supply and ash discharge locking systems (the systems containing several rotary star valves which get easily blocked by larger metal scrap). Temporary measures were taken again to remove the metal from the fuel by hand, based on metal detector signaling. This measure was partly successful, but could not be upheld by lack of sufficient personnel. Therefore, all wood chips in the main storage silo were returned to the wood supplier, starting a new metal removal campaign. Also, the decision was made to permanently modify the chipping plant at the wood supplier's by improving the Ferro metal separation and adding a new non-Ferro separator. These modifications took effect during November and December 2000.

- Filter fire

After the first gasification run, a baghouse filter for fly ash (with internal Teflon filter bags) caught fire, when due to an operation error, air was blown through the waste heat boiler and baghouse filter while still hot. The Teflon bags in the baghouse filter were replaced and the start-up program altered, so as to not allow air flushing unless the baghouse filters were by-passed.

- Gas reheater fouling

After wet gas cleaning the gas is reheated slightly to dry before being burned in the main boiler. The gas reheater (a steam heated heat exchanger) suffered from severe fouling by remaining fly ash in the gas after wet cleaning. The reheater had to be taken off-line several times and cleaned.

The decision was made that a new, less sensitive design was required.

- Fly ash flow characteristics

During the first gasification runs, discharge of fly ash from the filters turned out to be very problematic. The fly ash did not want to flow from the filter house cones towards the discharge screws. Major modifications of the filter house cones were initiated, including air fluidization pads and nozzles, "big blasters" (high pressure gas injection guns) and stainless steel lining of the filter house cones.

Other measures to improve the fly ash flow characteristics were tried, like increasing the specific weight of the ash by recycling more fine material back into the gasifier. Since fines will mostly pass the cyclone, the dust loading of the gas will increase and so will the specific weight of the ash. Fines can be derived from adding more and finer fresh sand, or from selected materials with an acceptable and preferably catalytic composition (dolomite or coal boiler-ash).

- Gas cooler fouling

Initially, several gasification runs were made with run lengths limited to less than 10 hours due to rapid and severe fouling of the heat exchanging surfaces of the gas cooler. The gas cooler (waste heat boiler) is located directly downstream of the gasifier cyclone. The steam raising gas cooler is expected to cool the product gas down to a temperature below 250°C in order to meet the allowable temperature of the baghouse filters.

Fouling of the heat exchanging surfaces was found to be caused by wood fly ash in the gasification mode. I.e. during the combustion mode the fly ash behaved much better, passing the heat exchanger and hardly causing any fouling in that mode at all.

In the gasification mode, the outlet temperature after gas cooling, as well as the pressure drop over the cooler, increased rapidly, so as to limit the first few test runs to no more than a few hours. As a temporary provision a water injection nozzle was installed to further cool down the gas after gas cooling (and to allow for somewhat longer run times). Longer runs were needed to test the gas cooler behavior during stable process conditions.

After a number of test runs (each run consuming much precious commissioning time, since the cooler had to be cleaned off-line, time and again, requiring a cool down period each time of more than a week) the conclusion was reached that the gas cooler and the associated process conditions had to be modified:

1. the distance between the heat exchanging surfaces was to be enlarged in order to avoid bridging and blocking
2. the rapping devices for pipe surface cleaning were to be modified and optimized
3. the gas velocity was to be made more equal over the full cross section of the cooler, and to be slightly raised

5.4 Technical operational results

As described in the preceding chapter, up to the close-out date of May 2001 the plant has been operated at loads from 50 to 60-70% fuel input. Further, bed material throughput and air/fuel ratio are still to be optimised.

The fuel applied is shreddered demolition wood, sieved at a size of 50 mm. An indication of the composition up to now:

- moisture: 19 - 25 %;
- contaminants: 0 - 1 %;
- ash: 2 - 4 %;
- lower heating value (as received): 13 - 14 MJ/kg;
- nitrogen: 1 - 2 %;
- chlorine: 0.05 - 0.1 %;
- lead: 250 - 600 ppm;
- zinc: 200 - 500 ppm;
- sulphur: 0.07 - 0.15 %.

The basis bed material in the gasifier is sand.
In addition, coal fly ash was used, for both the catalytic effect in the gasifier and the improvement of the flow characteristics of the fly ash. The flow characteristics have temporarily been problematic, but by addition of coal fly ash into the gasifier, this problem was solved.

Due to the relatively high air-to-fuel ratio which has been applied up to now, the CO-content of the product gas has been between 9 and 11 %, and due to that, the cold gas efficiency is below the guarantee values.
This air-to-fuel ratio is discussed further in section 5.5.

The fly ash filters, equipped with PTFE filter bags, are sensitive to temperature elevation, but, when they are well in order, the dust content after the filters is below about 10 mg/m^3.

At the close-out date of this report, the operating hours of the plant in gasification mode including gas combustion in the coal boiler have been limited to almost 500. However, most of the operation time has been in May 2001: during the first half of that month, the availability of the plant was 75 %, of which 60 % in gasification mode.

The gas cooler (boiler) shows rather stable performance up to now. Fouling factors increase with decreasing temperature: the stable efficiency factors of the surfaces vary from 0.8 - 0.9 at 600 - 900°C to 0.2 - 0.3 at 350 - 500°C. The background of this temperature-dependence is being studied.

The effects of burning the wood gas in the coal fired boiler are very positive. They can be summarised as follows:

- the wood gas, together with the condensate bleed stream, which is injected into the boiler, has no negative effect on the NO_x emissions of the boiler, although the ammonia stripper in the gasification plant has not yet been in operation;
- no effects have been found on the fly ash quality or the gypsum quality;
- no influence has been found on the fouling behaviour of the coal boiler.

5.5 Discussion of Technical Data

The measurement results of the present operation situation of the plant do not yet correspond with the base case design data because of the following facts:

- up to now, the load of the plant has been limited to 60 - 70 % of full load;
- air-to-fuel ratio of the gasification has been limited up to now (λ = 0.40);
- bed material consumption of the gasifier has not yet been optimised.

To these points, the following remarks apply:

- During the first months of hot commissioning, the gas cooler was fouling and blocking with fly ash very quickly. No stable operation was possible then. Then, it was decided to modify the existing gas cooler according to the design starting points that were defined on the basis of the fouling behaviour of the fly ash, in order to test these starting points with respect to a definite design.
  However, these design starting points require a bigger specific gas cooler volume, which means that modification of the existing boiler could only result in a cooler that is only suited for a limited load condition of the plant.
  The above includes that a definite (bigger) modification or replacement of the gas cooler is to be realised still.
- The gasification process was designed for λ-values of 0.3 to 0.35.Up to May 2001, λ has been no lower than 0.38 - 0.40. This was done as a temporary condition, to be sure of conditions that allow for stable gasifier and gas cooler operation, and keep (far) away from tar producing conditions. These λ-values have now shown to be successful in this respect, with gas temperatures in the gas cooler down to about 350°C.
- As mentioned above, during the first months of hot commissioning, no stable gasifier operation was possible, due to rapid gas cooler fouling. Although runs were short then, it also became clear that the flow characteristics of the fly ash was bad: the fly ash did not flow through the cones of the filter houses into the conveyor screws. Then, it was decided to feed an additive to the gasifier, in parallel with the sand. Fly ash from the coal fired boiler of the power station was chosen as additive, because the particle size was small enough so that most of it would directly be transported from the gasifier, entering the gas cooler together with the gas. This makes the fly ash more dense. This measure was successful: the flow characteristics prove to be much better since then.
  The next step is now to optimise the quantity of additives that is fed into the gasifier. Limiting the amount of additives is important because big amounts can cause wear problems and capacity problems in the solids transport systems.

6. Lessons Learned and Special Topics

6.1 Lessons Learned

Lessons learned on specific biomass aspects
- poorly organized biofuels market, requiring specialized contracting
- clean biomass does not come cheap, requiring high conversion efficiencies
- hot commissioning requires adequate time and should not be underestimated by the equipment vendors

These lessons were addressed as follows:
- The *market for secondary fuels is still poorly organized and developing.*

Special attention must be paid to adequate guarantees of fuel supply in the long run. In case of this project, a long term fuel supply contract was entered and closed even before the equipment was put on order. This fuel contract includes continuous monitoring of the developments during the first phase and the build-up of a strategic wood fuel reserve of a minimum of 75,000 tons, to be available at start-up and to be kept available during the operational lifetime of the plant.

- *Clean biomass does not come cheap.*
  This precondition has led to the choice for cheaper B-quality contaminated demolition wood. B-quality includes contaminates like paint, glue, metal parts, etc. The price difference with clean wood compensating for the additional investment in extensive gas cleaning facilities.

- Experience to date shows that a period of 4 months for *hot commissioning and test runs,* as originally planned for by the vendor, has been *too optimistic* for this new and complicated technology

6.2 Special Topics

Generic biomass design considerations
Using biomass as a feedstock requires careful consideration to certain specific and unconventional design problems:
- low energy density (high specific volume), requiring relatively large sized equipment
- conversion technologies are relatively new, requiring both design and commissioning attention
- contrary to expectations, conversion of biomass is a quite complex operation, requiring thorough attention to detail

These generic design considerations were addressed as below:
- The *low energy density* of biomass (< 3 GJ/m^3 for demolition wood) requires an optimized logistic system. This was realized by contracting the full amount of wood fuel with one supplier only and through just-in-time delivery, thereby minimizing fuel handling and omitting of on site fuel pretreatment (wood chipping, sieving and magnetic separation).

- *Conversion technologies for biomass are relatively new* and thus imply uncertainties and risks. In this project, gasification was chosen over combustion, based on the necessity for gas cleaning, originating in the choice for contaminated waste wood. When gasification is chosen, the gas volume to be cleaned is much smaller than in the case of combustion. At the other hand, present world wide experience with biomass gasification is limited. Especially the combination of biomass gasification with gas cooling and filtering is rather new. This entails that substantial technical and commercial risks cannot be excluded.

Previous gasification experience gained through NV EPZ participation in the Demkolec coal gasification project (IGCC), turned out to be very important. Based on that experience decisions could be made and designs adjusted, where otherwise a relevant decision basis would have been missing.

- The observation that *biomass conversion is complex* does not only hold true for contaminated biomass (like demolition wood) but for green biomass as well.

Complex in the sense of complicated, this translates into: expensive. Therefore, complex plants can only be feasible at a larger scale, the reason why in this project the scale was adjusted upwards from 100,000 to 150,000 tons of wood per year.

The fact that a plant is complex (i.e. expensive) also requires a continuing search for design simplifications. In this project major simplifications could be made by making maximum use of the existing (support) services of the main power plant.

The following systems and services were combined:

- steam and condensate
- cooling water, natural gas, instrument air, etc.
- injection of waste water bleed into the coal boiler
- combined control room and shared operating shift personnel.

7. Publications, Presentations and Site Visits

Publications

At the release date of the Report 10 papers and articles on the project were published in a variety of distinguished magazines and conference proceedings.
The complete list of Publications is added in the back of this report.

Presentations

At the release date of the Report 15 public presentations on the project were held in a variety of locations, both on site, elsewhere in The Netherlands and in several European countries.
A complete overview of the Presentations is presented as a Table in the back of this report.

Site Visits

At the release date of the Report 32 site visits were hosted for a variety of international guests. These guests included representatives of the participating Contractors to the EU on the project, politicians, government officials, energy agencies, scientists from R&D institutes and universities, journalists and vendors. A complete overview of Site Visits is presented as a Table to the back of this report.

8. Conclusions and Recommendations

Large gasification plant extremely clean

The atmospheric circulating fluidized bed gasification plant for demolition wood built by NV EPZ for Amergas BV at the Amer Power Station at Geertruidenberg, The Netherlands, currently is one of the biggest biomass gasification plants world wide.
Equivalent electrical generation capacity is 29 MW_e, with an annual CO_2 emission reduction rate of 170,000 tons.

Due to a complex arrangement of gas cooling and cleaning facilities, this biomass conversion plant delivers a steady flow of extremely clean wood-derived LCV product gas, fit for firing or cofiring in any boiler installation with the most stringent fuel quality specifications. Furthermore, the combined emissions from the cofired LCV product gas and coal fired main boiler indicate that the net effect of the cofired wood gas on the overall NOx emissions of the main plant is negligible, if not even positive.

The plant design resulted in a technologically attractive solution for large scale conversion of (slightly) contaminated biomass into renewable electricity and heat.

Investment and financing

By making optimal use of the support facilities of the main power plant, investment and operating costs were limited. Investment costs of the complete gasification plant, including cofiring facilities, amount to approximately Dfl 1 million per MW-thermal.

Financial support through tax incentives as well as through project support by both EU and the Dutch government, was required to make this project financially feasible.

Recommendations for further Technology Development

The situation at the close-out date leads to the following recommendation to further implement Technology Development, concentrating on the following items:

- *improvement of the conversion rate* leading to lower Carbon content in the ashes, higher conversion efficiency and lower content of heavy hydrocarbons in the product gas

- *optimization of gas cooling and cleaning*, depending on the intended application of the gas. In this respect the following variables are of importance:
  -optimum gas filtering temperature
  -optimum gas cooler outlet temperature in view of the temperature relationship of the gas cooler fouling mechanism
  -gas filtering efficiency as required, dependent on the subsequent gas cleaning steps

- *improvement of the solids sluicing systems* (into and out of the pressure boundary of the gasifier vessel), especially with respect to:
  -blocking tendencies due to foreign particles of larger size (metal ware, stones etc)
  -wear
  -gas leakage/seal gas consumption

LIST of REFERENCES

Ref 1 "Addressing the Constraints for Successful Replication of Demonstrated Technologies for Co-combustion of Biomass/Waste"
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Proceedings EU Seminar "The Use of Coal in Mixture with Wastes and Residues II",
October 19-20 2000, Cottbus.

Cornelissen F., *"Duurzame elektriciteit"*,
Mens en Wetenschap No.7, November 2000.

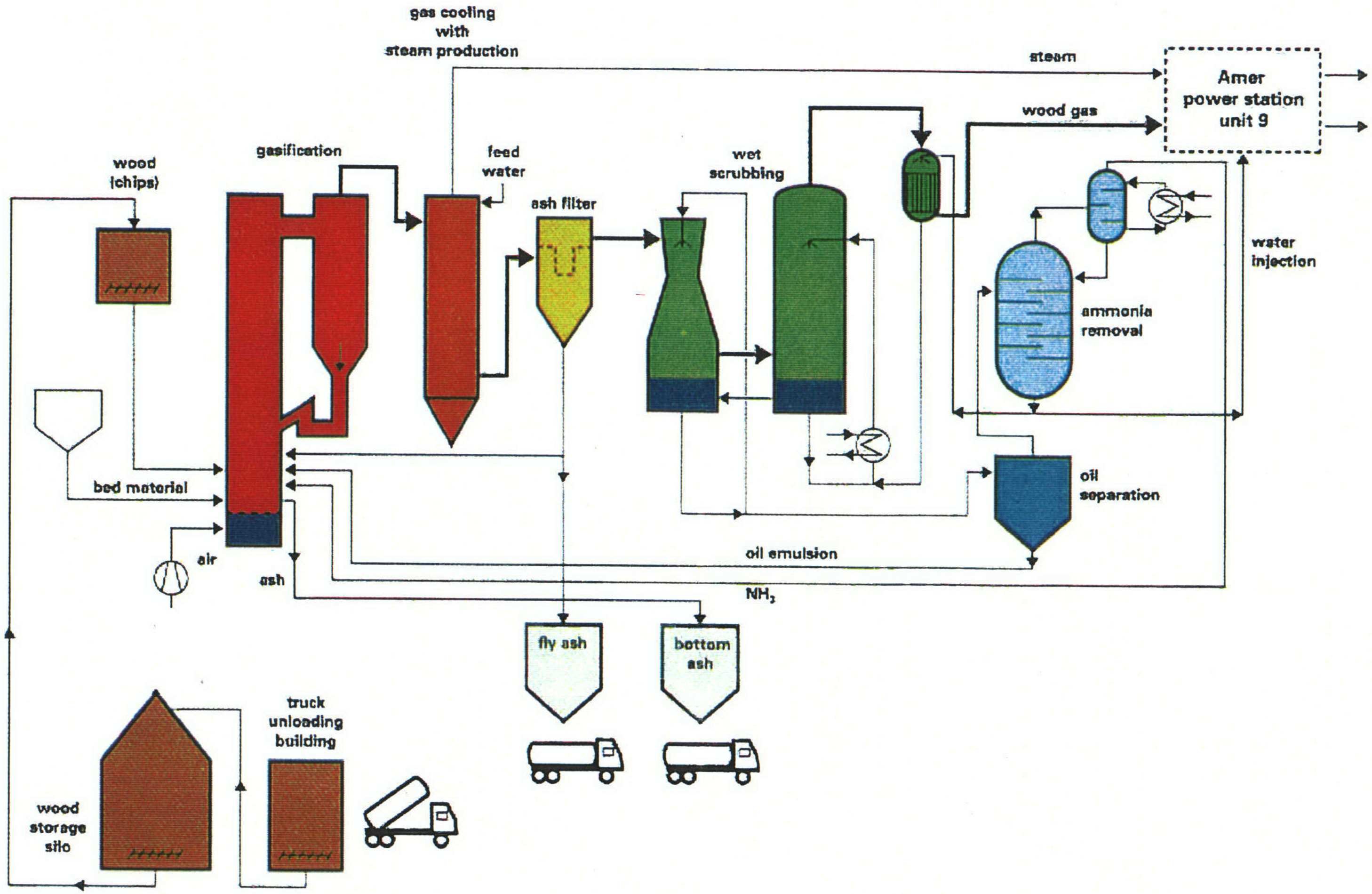
LIST of PRESENTATIONS

Date	Congress	Title	Location	By
-98	Markt voor Energie uit Afval en Biomassa 1998	Project Houtvergassing Amercentrale	Roermond (NL)	J. de Jong
-98	EU Seminar		Athens (Greece)	J. de Jong
-98	EU Seminar Biomass Gasification	Biomass Gasification Amer	Brussels (B)	Willeboer
03-03-99	Congress Duurzame Energie (NSC)		Gouda (NL)	Willeboer
03-06-99	PowerGen Europe	Big Wood Gasification Plant under Construction	Frankfurt (D)	Willeboer
29-09-99	TV Shooting		Geertruidenberg	Willeboer
14-10-99	Conference VGB Kraftwerke	Großanlage für die Vergasung von Biomasse nimmt Betrieb auf	München (D)	Willeboer
03-11-99	Markt voor Energie uit Afval en Biomassa 1999	Biomassavergassing Amercentrale	Nijmegen (NL)	Willeboer
03-03-00	NOVEM Seminar Biomassa-vergassing	Biomassavergassing Amercentrale	Utrecht (NL)	Willeboer
06-04-00	IEA Task Meeting Biomass Thermal Gasification	Biomass Gasification at Amercentrale	Enschede (NL)	H.Smeets
24-05-00	Symposium Biomassa: vergassen, verbranden en vergisten	Biomassa Vergassing op Grote Schaal in Geertruidenberg	Jaarbeurs Utrecht (NL)	Willeboer
08-06-00	First World Biomass Conference	Cofiring of Biomass Derived Fuels in Coal Fired Power Stations	Seville (Spain)	J. de Jong
06-07-00	ECOS 2000	Biomass Gasification in Geertruidenberg, The Netherlands	Enschede (NL)	Willeboer
19-10-00 20-10-00	EU Seminar Use of coal in mixtures with wastes and residues	Amergas Biomass Gasifier starting operation	Cottbus (D)	Willeboer
02-11-00	Markt voor Energie uit Afval en Biomassa 2000	Realisatie van de Biomassa Vergassingsinstallatie	Geertruidenberg	Willeboer

LIST of SITE VISITS

Date	Party	Country	Partic pant
21-01-99	VTT (Contractor to the EU on this Thermie project)	Finland	2
02-02-99	ECN	TheNetherlands	2
24-02-99	NOVEM	TheNetherlands	2
27-05-99	Elkraft (Contractor to the EU on this Thermie project)	Denmark	2
22-10-99	Elektromark, Ruhrverband (via Lurgi)	Germany	4
17-11-99	Wisvest Group, Residual Technology, Al Group, ETI Group (via Lurgi)	USA	
23-11-99	International Workshop KEMA/NOVEM	misc.	23
25-11-99	HEW /Mr Tiedt (via Lurgi)	Germany	1
14-02-00	AVR Holding	TheNetherlands	4
25-02-00	Russian delegation (VN wood project)	Russia	20
16-03-00	Shell Renewables /Messrs. VanOorsouw, Furze, Hazlewood	TheNetherlands	3
29-03-00	Sita BFI /Messrs. Bertu, LeGrand	TheNetherlands	2
30-03-00	Energieconsulting Heidelberg /Mr Berger	Germany	1
07-04-00	Members IEA Bioenergy Activity	misc.	23
10-05-00	Participants GUA-meeting (via Essent)	misc.	± 40
30-05-00	Members IEA Biomass (via Essent)	misc.	± 40
08-06-00	Members KIVI	TheNetherlands	± 25
04-07-00	Pre-conference excursion ECOS 2000	misc.	34
04-07-00	Arbre Energy Ltd /Messrs. B.Paterson (Bus. Man), P.Shaw (Op.Man), Stramproy SPS /H.Veltmans (Sales Manager)	UK TheNetherlands	4 1
31-08-00	Arbre Energy Ltd / Messrs. B.Paterson, A.Jones, M.Dickinson, M.Hawkins (return visit EPZ to Arbre on 18-01-2001 with 6 participants)	UK	4
08-09-00	CDA Brabant Equipe (via C. Knoop)	TheNetherlands	
11-09-00	Vaste Kamercommissie Milieu, Novem, Essent	TheNetherlands	10
01-11-00	Congress participants: Markt Energie uit Afval en Biomassa	TheNetherlands	130
15-11-00	IEA Clean Coal Science Group	misc.	10
16-11-00	Journalists covering TheHague IPCC Climate Conf. (GHG)	misc.	20
16-11-00	VGB-working group (via NV EPZ/A.Korthout)	misc.	20
23-11-00	International Port Management	misc.	20
29-11-00	NV Essent / Corporate Communications	TheNetherlands	
	Kloeckner Wood Techn. GmbH visiting Raumaster silo's (via NV EPZ/ MvdGevel)	Germany	
31-01-01	Projectbureau CO_2-Reductieplan /dr.R.F. Wielinga	TheNetherlands	1
08-02-01	Tech.Univ Eindhoven /students	TheNetherlands	19
21-09-01	Ned.Ingenieursvereniging (NIRIA), West-Brabant region	TheNetherlands	

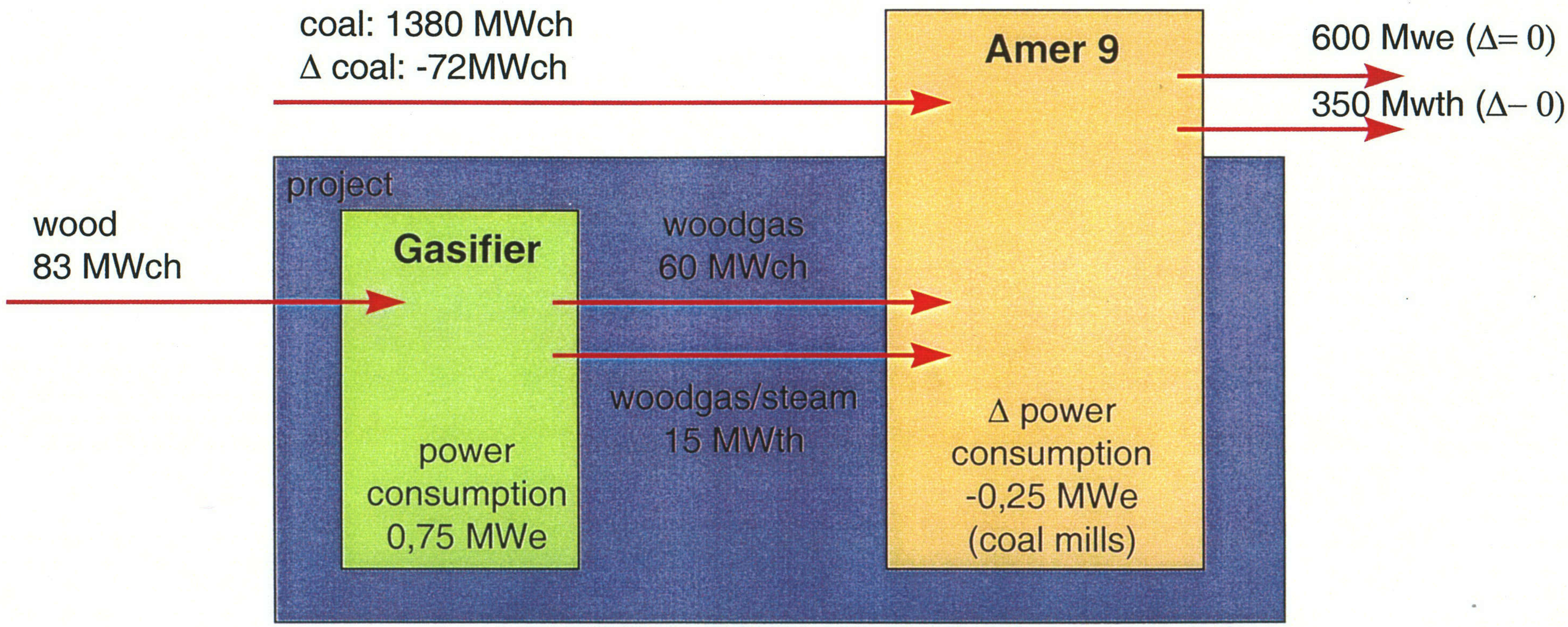
SCHEMATICS



Schematic process diagram wood gasification

Amergas: woos gasification at the Amer power station

Energy balance Amer 9 with gasifier



Amer 9 power station nr. 9 with wood gasification plant

1 november 2001