Turkish Coal Enterprises

Development of Gasification and Activities in Turkish Coal Enterprises

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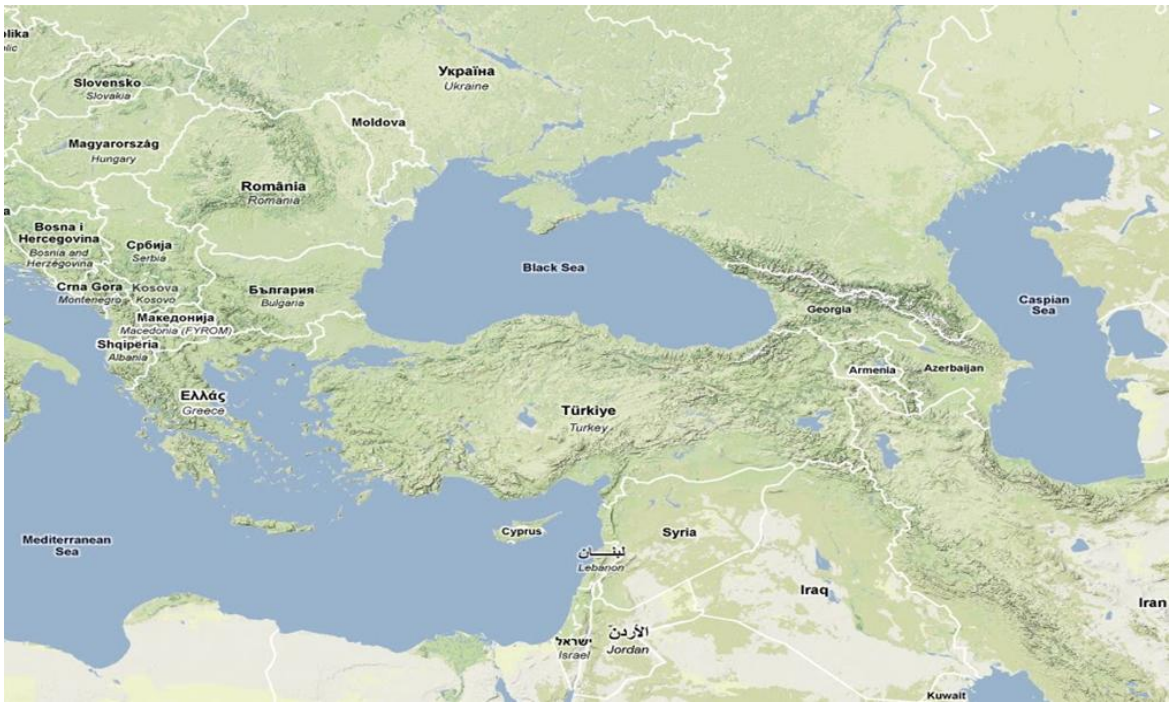
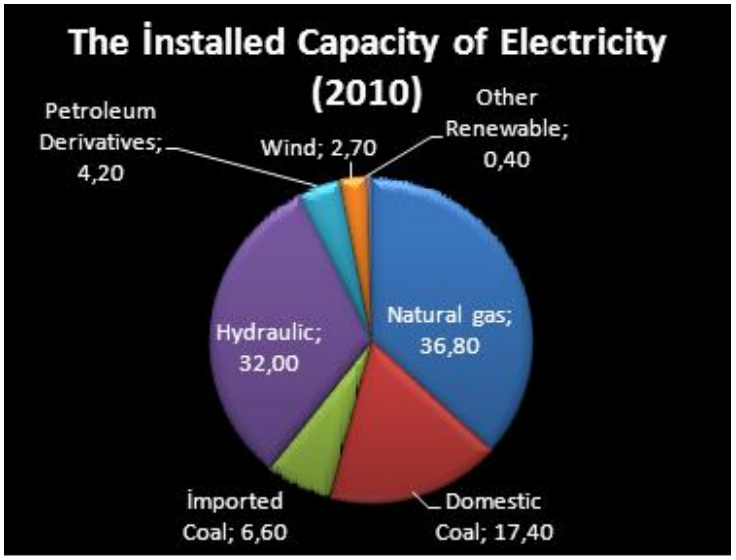
REBUPLIC OF TURKEY

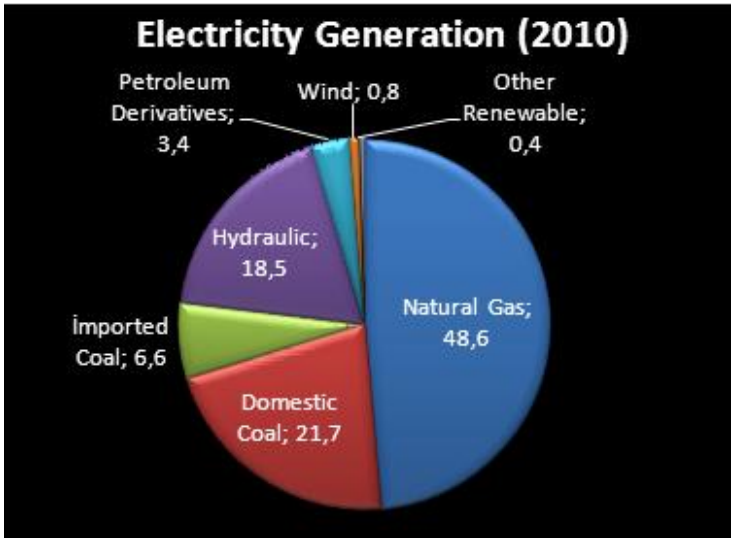
- Functioning as a bridge between Europe and Asia
- Population: 74.000.000
- Surface area: 814.578 km²
- Exports (2010): $113.686.000.000
- Imports (2010): $185.493.000.000
- Growth rate (2010): 8,9%
- National income per capita (2010): 10.079$



ENERGY DATA OF TURKEY

- Turkey is not very rich in terms of energy resources, therefore it is dependent on outside on a large scale
- Dependency rate of energy changes between %70-75
- Energy import for 2010 is 38,5 billion dolars, for 2011 estimated between 45-50 billion dolars
- Turkey's current deficit is largely due to energy import
- 2010 Electricity consumption of Turkey is 210.182.000.000 kwh
- Annual increase rate in electricty consumption is between %6-8

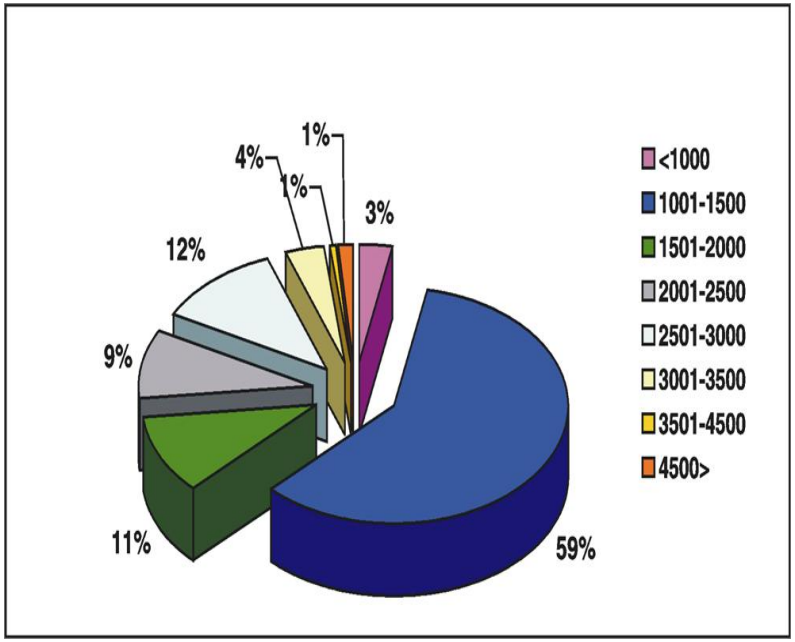




COAL DATA OF TURKEY

- Coal is one of the most important energy sources of Turkey.
- It has 12,4 billion tons of lignite and 1,3 billion tons of hard coal deposit
- 85 million tons of lignite and 2,5 million tons of hard coal are produced annually
- Additionally 20 million bituminuous coal is imported every year.
- 1/4'th of all coal is utilized for electricity production, remaining is used for industry and heating purposes
- Turkish lignites are generally low grade coals

Distribution of Average Calorific Values of Turkish Lignites



Coal Deposits in Turkey, 2009

TURKISH COAL ENTERPRISES (TKI)

- TKI, which was established in 1957, a State-Owned Economic Enterprises,
- TKI which carries out lignite production is among leading mining companies in Turkey
- Approximately 8200 personel have been employed
- For 2009 annual income is 1,5 billion dollars, profit 280 million dollars
- For 2010 annual income is 1,45 billion dollar, profit 230 million dollars
- In ranking of first 500 companies in Turkey, TKI is 16th for 2008, 18th for 2009
- Annual production of TKI changes between 35-40 million tons
- TKI has 2,6 billion tons of lignite deposit that consists of 21% of Turkey's total lignite
- In fact, TKI owns important lignite sites and they are comparatively high grade coals
- TKI fulfills coal requirement of total 4250 MW thermal power plants.

WHY AND WHAT RESEARCH AND DEVELOPMENT?

Due to;

- ✓ low rank of coal (low calorific value, high ash, humidity, sulfur etc.)
- ✓ being one of the most important energy sources of Turkey
- ✓ dependency of Turkey to other countries on energy sources
- ✓ signing of Kyoto Protocol by Turkish Government (some sanctions may be the case in coming years)
- ✓ need to increase productivity and value-added by advanced technology.

TKI have been performing research and development activities for 5 years

R&D activities are mainly comprised of;

- ✓ coal preparation and enrichment
- ✓ gasification, related of which gas cleaning, gas conditioning and separation, fuel and methanol production
- ✓ coal mining and coal exploration
- ✓ coal-derived products (e.g. Humic acid)

TKI'S R&D PROJECTS RELATING TO GASIFICATION

TKI's gasification R&D Projects can be grouped into three categories

1. Conventional Gasification Projects

   1.1 TKI Pilot Gasification Projects
   1.2 T Liquid Fuel Production From Biomass and coal blend - Trijen Project
   1.3 Feasibility study for Turkish Lignites gasification (USTDA supported)

2. Underground Gasification Projects

   2.1 Research and analysis of underground coal gasifying in the laboratory environment
   2.2 Underground Coal Gasification Analysis for Turkish Coal Enterprises

3. Advanced Gasification R&D Projects

   3.1 Coal Gasification via Plasma Application
   3.2 Methane Production by Coal Biotechnology

TKI COAL GASIFICATION PROJECTS
(Selection of types and capacities of gasifiers)

Gasifiers comparision

	Fixed bed	Fluidized bed	Entrained bed
Coal type	Non caking	Non caking	All types
Grain size	5-50 mm	0,5-5 mm	0-0,5 mm
Gasification time	15-20 min.	0,5-1,5 hour	<10 second
Gasification medium	Air/ oxygen/ steam	Air/ oxygen/ steam	Steam/ oxygen
Exit Gas temprature	400-500 ^{o}C	700-900 ^{o}C	1350-1500 ^{o}C
Pressure	0-40 bar	0-10 bar	0-40 bar
Carbon yield		%65-85	98%
CO+ H_2	%55-60	70%	85%
Wastes	Tar, phenol	-	-

- TKI has decided to build two pilot coal gasifier plants. In order to gain experience, TKI engineers have participated in design, project and mounting works, and will carry out R&D studies on gasifiers
- Entrained bed gasifier has been preferred for main plot gasifier, because:
  - All types of coal can be used
  - Rate of beneficial gas composition (H_2+CO) is high
  - Rate of carbon yield is very high
  - Since the gasifier will work at 1500 C, ash will not be caked
  - No pollusion because of tar and phenols
- Capacity of entrained bed gasifier was chosen as 250 kg/hr so that R&D studies of gasification and following activities i.e. gas cleaning, gas conditioning, fuel and methanol production, electricity production can be performed
- For comparison purposes, a fluidized bed gasifier, which has second better features, with 20 kg/hr capacity was designed and built
- Erection of both gasifiers has been completed, start-up activities is going on. It is expected to produce syn-gas within few months

A PICTURE FROM 250 t/h ENTRAINED BED GASIFIER

DESCRIPTION OF 250 t/h ENTRAINED BED GASIFIER

250 t/h Entrained Gasification plant consist of 5 units:

1.Coal Preparation Unit

Capacity of the Unit is 1 ton/h

- 0-40mm original coal with max. 30% humidity is crushed by a hammer crusher to 10 mm
- Then is fed to a grinder and ground to 100 µ
- Humidity of ground coal is decreased to 5%
- The hot gas for drying is produced from light oil
- The dried and ground coal is transported to gasification unit under nitrogen pressure (denseveyor)

2. Oxygen and nitrogen tanks

- Oxygen and nitrogen requirements of gasifier will be met from 2 tanks, each will have a capacity of 10 tons
- There will be heat exchangers in the exit of the tanks
- Nitrogen pressure is adjusted between 0,5-1,5 bar, oxygen pressure is fixed as 0,5 bar

3. Preparation of cooling and boiler feed water

- Water is cleaned via sand filter, cation and anion exchangers
- Water need of the system is 2000 lt/h
- There is a 10 m^3 tank for processed water

UNITS OF 250 t/h ENTRAINED BED GASIFIERS (2)

4. Gasifier Unit

- Gasifier works under atmospheric pressure, gasifying temperature is 1500 °C
- Gasifier includes coal lock, coal screw, ash lock, quench section
- Gasifier and quench section are lined with refractory. These sections are not jacketed to produce steam
- Oxygen and nitrogen is fed to gasifier at 0,5 bar and 1.5 bar respectively
- Part of the molten ash leaves the gasifier to scrubber and remaining falls to underwater scrapper
- Gas is cooled to 950 °C at quench section by spraying water and leaves waste heat boiler at 300 °C

5. Water Clarifying and Ash Stocking

- Dirty water is clarified by adding Al_2SO_4
- Then water is pumped to clean water tank and cooling tower
- Ash gets rid of sticky feature by cooling at quench section and drops ash removing system
- Ash is transferred to conveyor belt by means of palette on ash removing system and the conveyor carries ash into ash pool

GASIFICATION DATA FOR 250 t/h ENTRAINED GASIFIER

Characteristics of the prepared coal for the gasifier

- Carbon….: 59,92%
- Hydrogen: 4,25%
- Nitrogen..: 2,08%
- Sulfur…….: 1,97%
- Oxygen….: 8,74%
- Ash……..: 18,05%
- Moisture.: 5,00%

According to results of gasifier design, used materials and achieved products are given below:

Used material:

- Coal……..: 250 t/h
- Oxygen…: 240 kg/h
- Nitrogen.: 70 kg/h
- Water……: 1834 kg/h
- Electricity: 160 kW

Products:

- Raw gas: 423 Nm^3
- Steam: 240 kg/h (30 bar, 235°C)

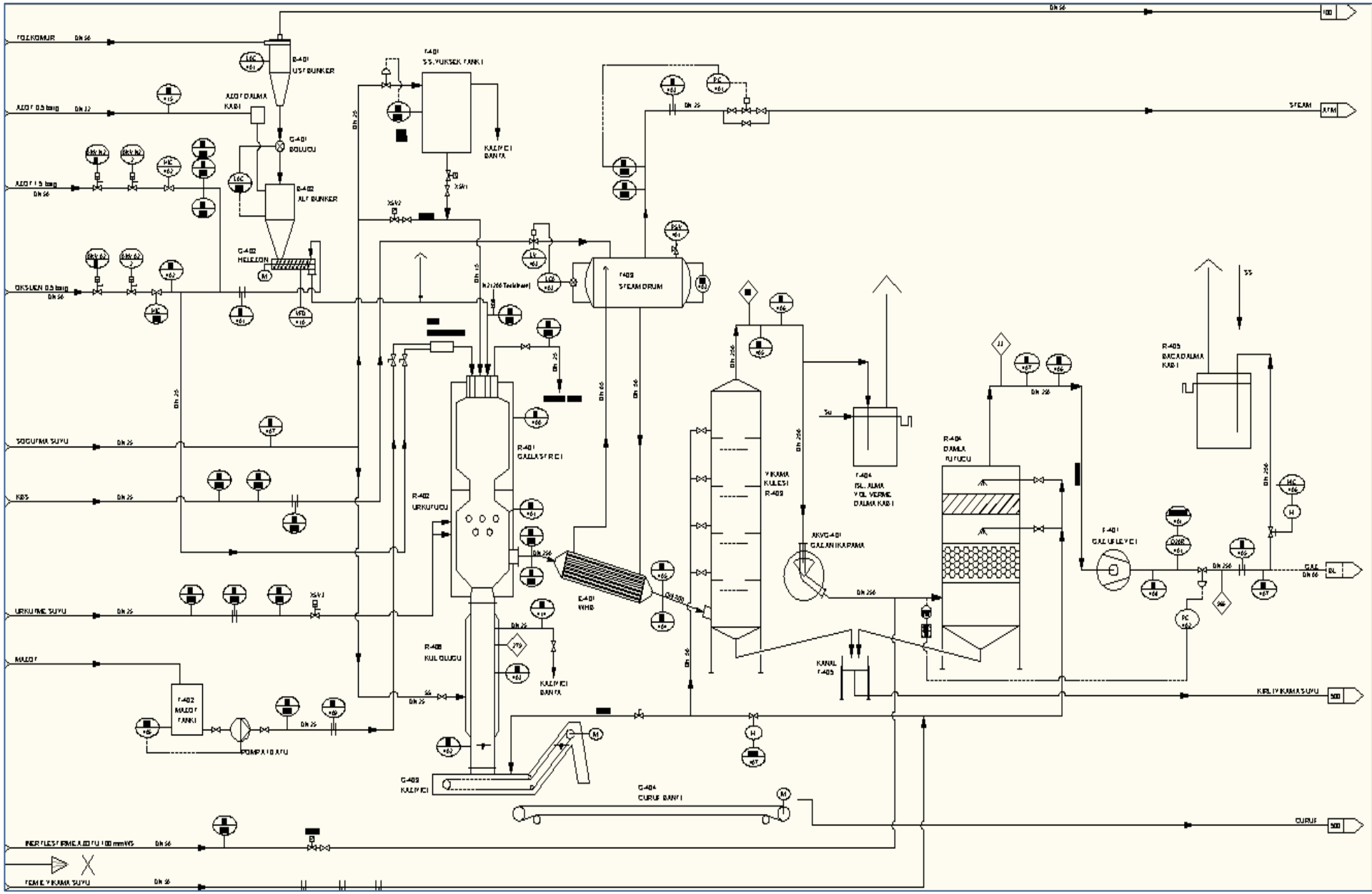
Wastes:

- Ash: 55 kg/h
- Water: 105 kg/h

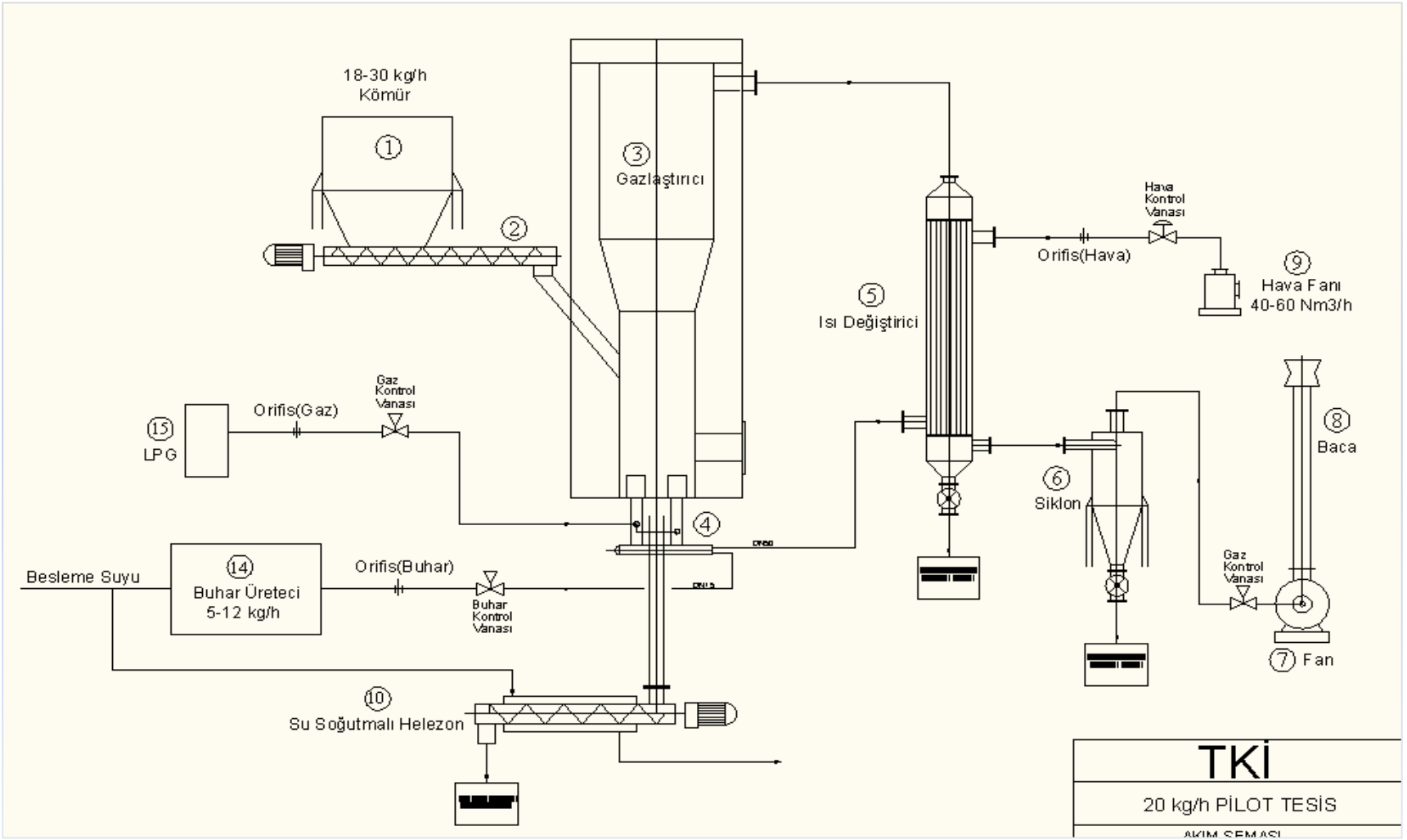
Raw Gas Analyses:

- CO.: 63,80%
- CO_2: 12,63%
- H_2..: 21,44%
- H_2S: 1,14%
- N_2..: 0,99%
- Flying ash: 1,93 kg/h

FLOW DIAGRAM OF 250 t/h ENTRAINED BED GASIFIER



FLOW DIAGRAM OF 20 t/h FLUIDIZED BED GASIFIER

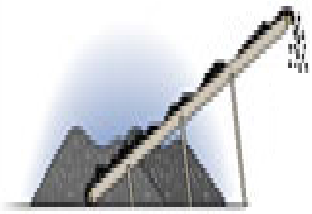


LIQUID FUEL PRODUCTION FROM BIOMASS AND COAL BLEND - TRIJEN PROJECT

AIMS

- to produce more economic, efficient and clean liquid fuels from coal and biomass,
- to enhance the utilization of the widespread national resources for sustainable development and energy security,
- to develop technologies to be used in industry,
- to demonstrate the outcomes in a pilot scale.

Coal & Biomass



Project Duration: 48 Months (2009 -2013)

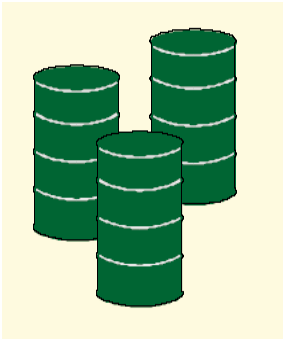
Customers: Turkish Coal Enterprises **(TKI)** and General Directorate of Electrical Power Resources Survey & Development Administration **(EIE)**

Partners: TUBITAK, ITU, MU, UMDE, HABAŞ

Supporting bodies: TUBITAK 1007 Programme

Research Areas:

- Fuel feeding system,
- Oxy gasification,
- Steam gasification,
- Gas cleaning,
- Gas conditioning and separation,
- F-T processes and catalysis (Liquid Fuel Production),
- Process control
- System integration

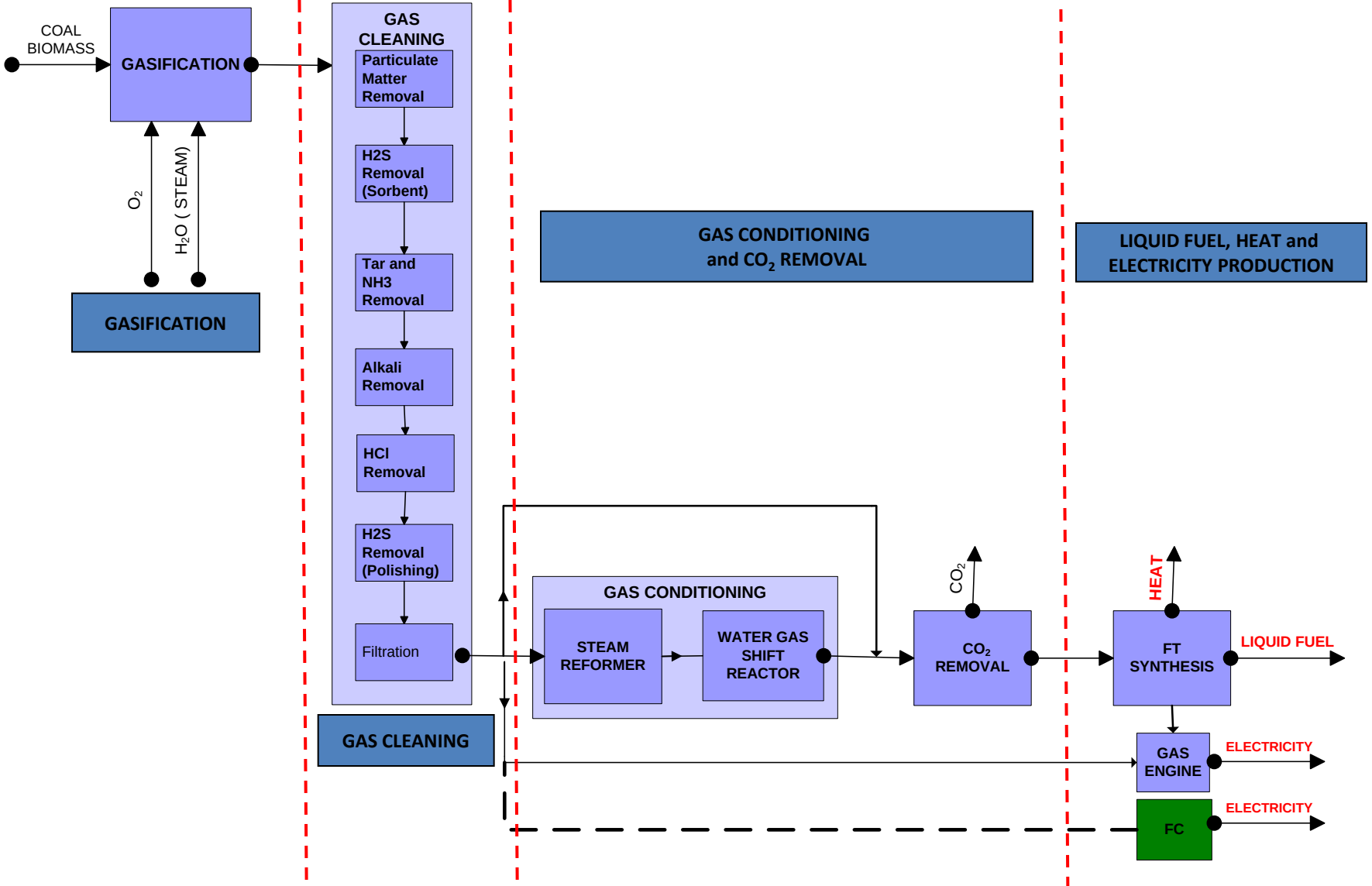


Liquid Fuel

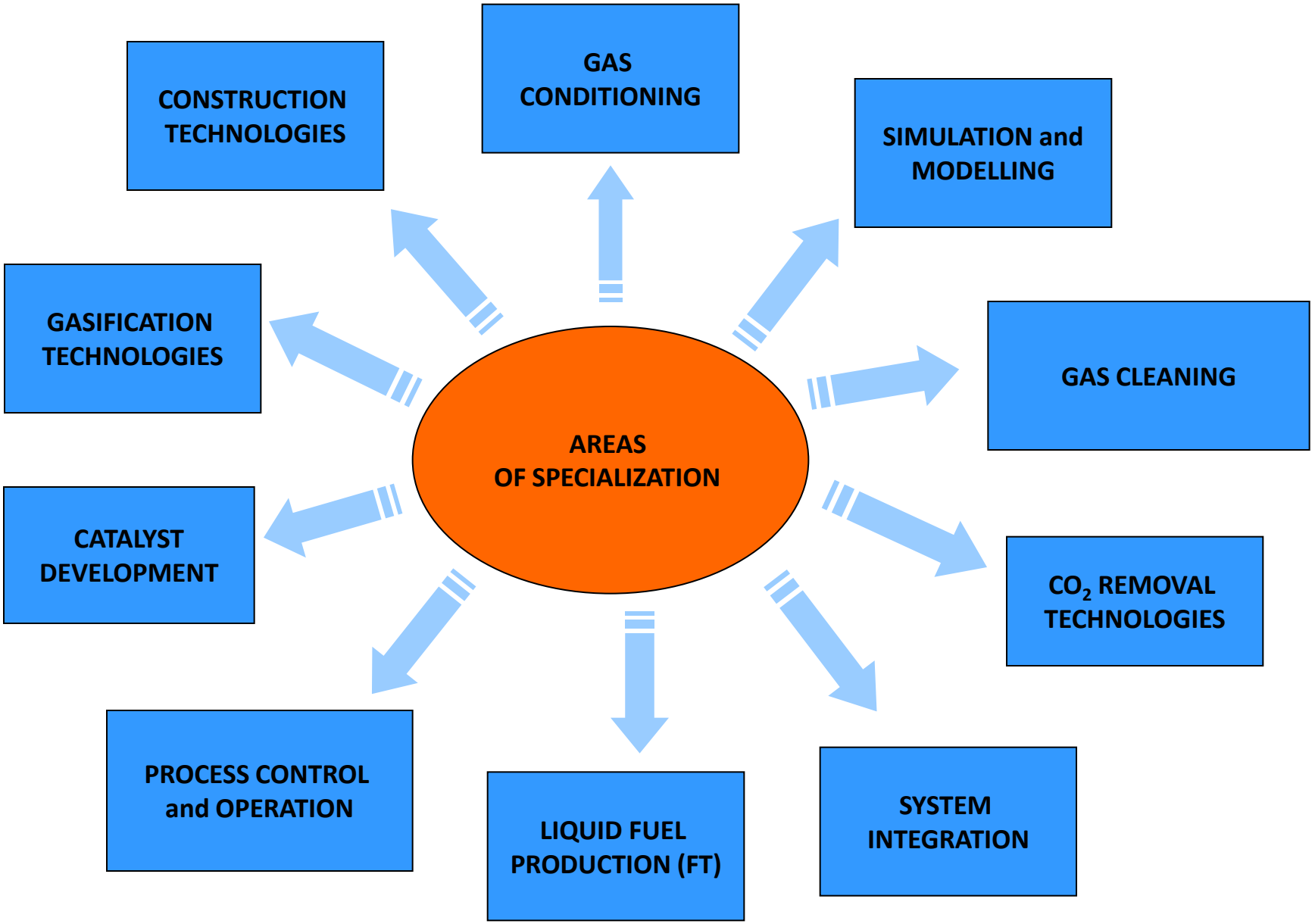
System capacity is 200 kg (lignite+biomass)/h and aprox. 1000 kWth feeding

LIQUID FUEL PRODUCTION FROM BIOMASS AND COAL BLEND - TRIJEN PROJECT

MAIN TECHNOLOGICAL RESEARCH AREAS



EXPERTIES and KNOW-HOW REQUIREMENTS OF THE PROJECT



LIQUID FUEL PRODUCTION FROM BIOMASS AND COAL BLEND - TRIJEN PROJECT

MAIN DELIVERABLES

- Pilot Scale CTL Pilot Plant (1000 kWth and 200 kg/h feed capacity)
  - Fuel feeding systems
  - Fluidized Bed Gasifier
  - Gas Cleaning Systems (Particulate Matter, H_2S, Tar, NH_3, HCl, Alkali)
  - Gas Conditioning Systems (Shift Reactors)
  - CO_2 Removal Unit
  - Fischer-Tropsch Reactor
- FT Catalyst
- Technical and Economical Feasibility Assesment for Industrial Applications

- Lab Scale Experimental Set Up
  - Fluidized Bed Gasifier
  - Gas Cleaning System (Particulate Matter, H_2S, Tar, NH_3, HCl, Alkali)
  - Gas Conditioning System (Steam and Shift Reactors)
  - Fischer-Tropsch Reactor (Liquid Fuel Production)

METHODOLOGY

GASIFICATION

GAS CLEANING

FLUIDIZED BED GASIFIER

- Gasification process
- Kinetic studies
- Design and regimes of gasifier
- Oxy and steam gasification
- Additive injection to bed material

PARTICULATE MATTER REMOVAL

- Cyclone Filter
- Ceramic Filter

H_2S REMOVAL

- Sorbent Bed
  (High temperature sorbents, Dolomite)
- Polishing
  (Low temperature sorbents, ZnO)

Tar and NH_3 REMOVAL

- Additive injection to gasifier
- Catalytic Tar Cracking

Alkali REMOVAL

- Adsorpsion (Bauxite, Kaolinite and similar clay based sorbents)

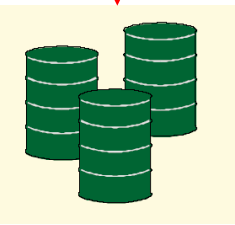
HCl REMOVAL

- Chemical reaction with alkali metal carbonates or oxides

METHODOLOGY (cont.)

GAS CONDITIONING and SEPARATION

LIQUID FUEL PRODUCTION via FISCHER TROPSCH SYNTHESIS



Gas Conditioning with Thermochemical Methods

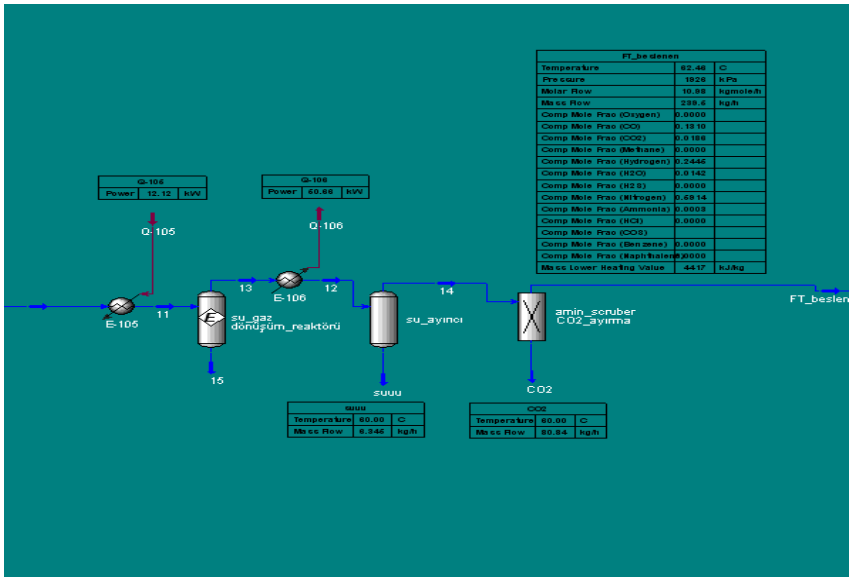
- Water Gas Shift Reactor (WGS)
  - Adjustment of H_2/CO ratio

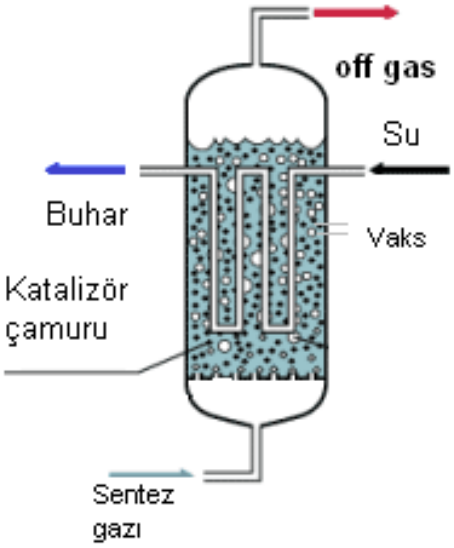
CO_2 Separation

- Absorption

Low Temperature (180- 250 °C) FT Process

- Slurry Phase Reactor
- Development of Fe based catalysts





GASIFICATION

150kWth Lab Scale CFB Gasifier (constructed)

1.1 MWth Pilot Scale Bubbling Fluidized Bed Gasifier (designed)

GAS CLEANING

- H_2S
- COS
- CS_2
- NH_3
- Tar (polyaromatic hydrocarbons)
- Soot and particles
- HCl, HF
- Alkali compounds

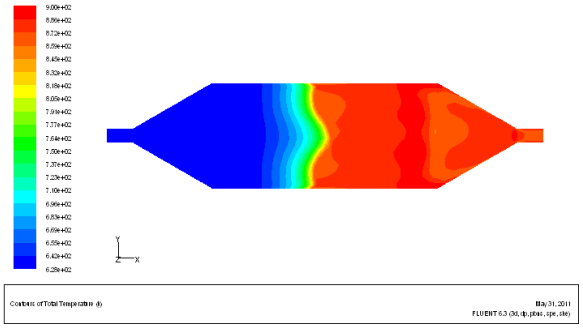
GAS CONDITIONING AND SEPARATION

AIM :

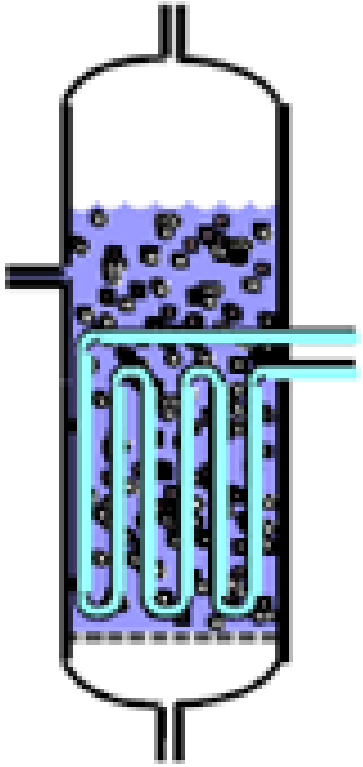
- H_2/CO = ~2
- CO_2 removal

METHODOLOGY:

- Water gas shift reactors for H_2/CO conditioning before FT reactor
- Chemical absorption for CO_2 removal



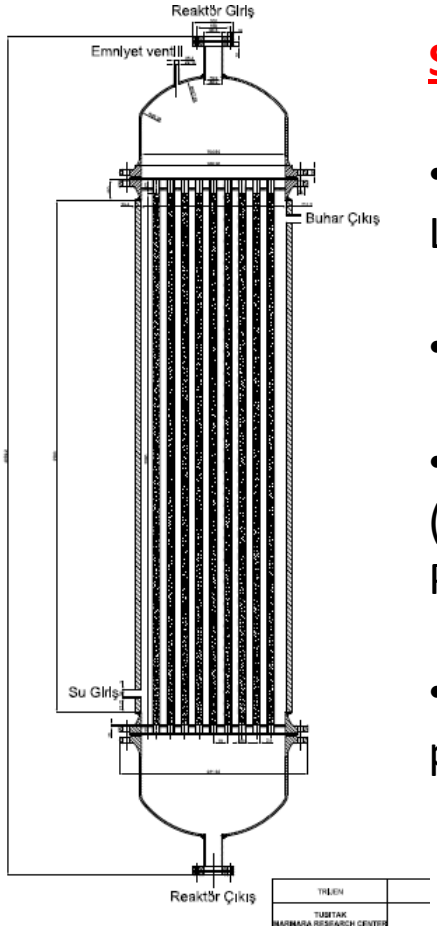
FISCHER-TROPSH SYNTHESIS



Slurry Bubble Column Reactors

Studies

- Kinetic Studies in CSTR
- Attrition Tests
- Cold Flow Hydrodynamic Studies
- Reactor Design for pilot scale system



Multi Tubular Fixed Bed Reactors

Studies

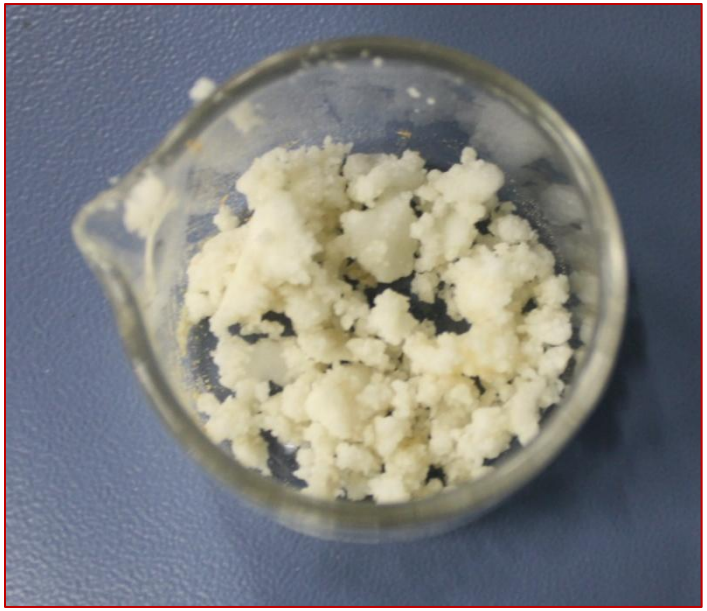
- Kinetic Studies in Lab Scale systems
- Optimization studies
- Modelling studies (Aspen HYSYS, Polymath, MATLAB)
- Reactor Design for pilot scale system

FISCHER-TROPSH SYNTHESIS

CATALYSTS

- Precipitated Fe-catalysts
- Supported **Fe** or **Co** or **Fe-Co bimetallic** catalysts
- Typical supports : Zeolites, Al_2O_3, ZrO_2

FISCHER-TROPSH SYNTHESIS



Wax product sample

Liquid product sample

FEASIBILITY STUDY FOR GASIFICATION OF TURKISH LIGNITES

- The U.S Trade and Development Agency (USTDA) provided a grant in the amount of US$437,020 to Turkish Coal Enterprises in accordance with a grant agreement dated August 27,2009 for coal gasification project
- In this project, technical, economical and financial feasibility of
  - Gasification of Turkish lignites in a gasification plant
  - Converting syngas into synthetic natural gas (SNG)
  - inserting SNG in gas transmission system
  - Or using it in an IGCC power plant in Turkey

  Will be assessed
- The company that would perform feasibility study idendified by means tender. Among 16 companies which offered for the tender, Worleyparsons was qualified
- All necessary information including coal analiyses data have been delivered to the company. The feasibility study is going on with respect to the schedule, it is expected to be completed in Nowember, 2011

FEASIBILITY STUDY FOR GASIFICATION OF TURKISH LIGNITES

- **The Project will be performed in 10 steps:**

- Purpose of Study and Preliminary Review
- Technology Screening Analysis
- Site Selection
- Conceptual Design
- Economic Analysis
- Financial Analysis
- Environmental Analysis
- Regulatory Analysis
- Development Impact
- Export Potential – U.S. Sources of Supply
- Implementation Plan
- Final Report

FEASIBILITY STUDY FOR GASIFICATION OF TURKISH LIGNITES

- Technical Analysis ;
  - Screen at least two commercial gasification systems to best meet future demand in Turkey.
  - Perform a screening of at least two sites identified in the preliminary site visit to choose the best locations to build these gasification facilities
  - Carryout a conceptual design of the gasification facility.
    - Technology screening evaluation,
    - Site selection at least two and up to 10 potential sites

- Conceptual Design
  - Design requirement document, which defines the design basis for the feasibility design,
  - Technical description of the gasifier and the gas cleanup train, at a conceptual feasibility level of design,
  - Equipment list, including major items of equipment, indicating quantities and level of redundancy,

FEASIBILITY STUDY FOR GASIFICATION OF TURKISH LIGNITES

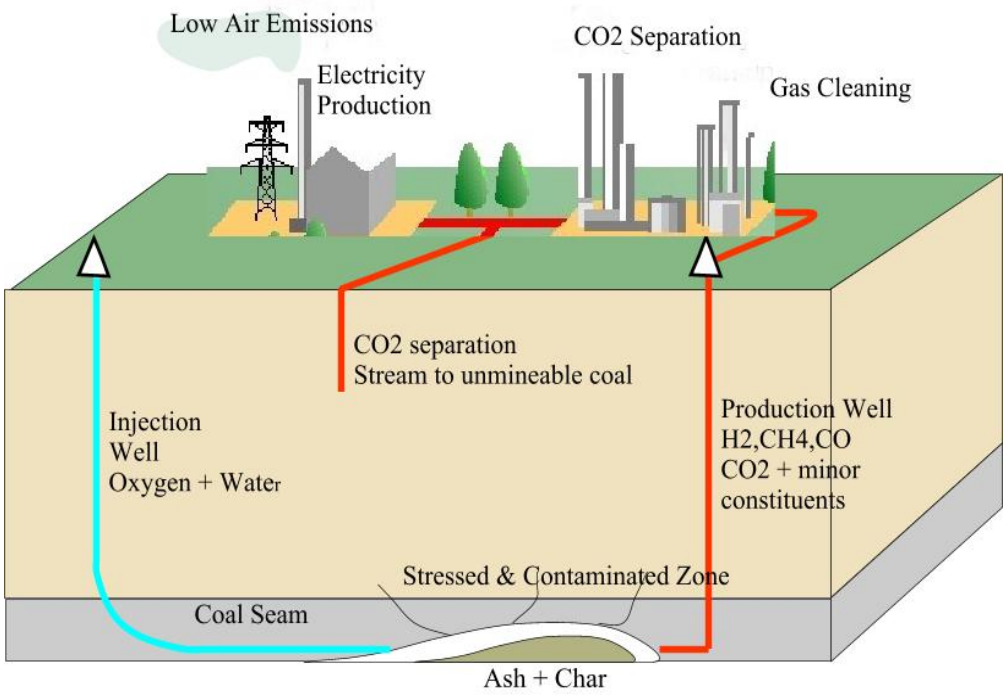
- **Conceptual Design (continued)**
  - Heat and mass balance at a single design ambient condition. The work shall be performed by adapting existing software models (heat and mass balances). Block flow diagram for the gasifier and gas cleanup train
  - Termal performance summary,
  - Air emissions summary ,
  - Plant inputs and outputs summary,
  - Water balance diagram,
  - Process blocks in a plan view,
  - Level 1 schedule for engineering, permitting, fabrication and construction, start up and commissioning,
  - Estimated availability trend for the gasification unit
  - Discussion of the treatment and disposition of tars and oil and butane/toluene and xylene (BTX), if appropriate.

- **Economic Analysis ;**
  - Capital Cost Estimate
  - Project Operating and Maintanenance Expenses
  - Projected Revenue
  - Cash Balance Pro Forma

UNDERGROUND COAL GASIFICATION (UCG)

- UCG is the gasification of coal in the seam-in-situ by using air or oxygen or air and oxygen together
- Air and oxygen injected down a borehole – produced gas called as synthesis gas is extracted
- UCG uses similar process to surface gasification except, the reactor is underground, in the coal seam
- UCG can be used on resources which are not otherwise feasible or economic to mine by open cast or U/G mining methods
- Although commercial application of UCG is limited, many experiments and trials have been realized up to today

HOW DOES UCG WORK?



Schematic of the components of the UCG process collocated with electricity generation (UCG Engineering, Ltd., 2006)

Performing steps of UCG:

- Step 1: Find the coal
- Step 2: Drill the boreholes
- Step 3: Link the boreholes
- Step 4: Ignite the coal
- Step 5: Inject the O_2 and steam
- Step 6: Extract the syngas
- Step 7: Gas cleaning
- Step 8: CO_2 separation
- Step 9: Use of gas (electricity production)

ADVANTAGES AND DISADVANTAGES OF UCG

- **Advantages:**
  - Much higher coal utility – up to 95%
  - Conventional coal mining is eliminated with UCG
  - Coals that are unmineable (too deep, low grade, thin seams) are exploitable by UCG,
  - More economic – less capital expenditure compared to traditional gasification
  - Potential to be cleaner technology (No production of some criteria pollutants e.g., SOx, NOx)
  - Trace elements of contaminants are left underground
  - Little or no rehabilitation required, UCG leaves environment largely untouched
  - No Ash (most of the ash in the coal stays underground)
  - Less greenhouse gas and has advantages for geologic carbon storage

- **Disadvantages:**
  - Underground water table contamination
  - Ground Subsidence.
  - The rate of water influx, the distribution of reactants in the gasification zone, and the growth rate of the cavity, cannot be controlled like surface gasifiers.

IMPORTANCE OF UCG FOR TURKEY AND TKI

- Turkish Coal Enterprises' (TKI) coals and other Turkey coals are mainly low-rank or soft coal (e.g. lignite)
- In Turkey, some lignite deposits are not mineable or mining is not economical. These deposits may be well suited for underground gasification.
- TKI has started a development program aimed at creating commercial coal gasification operations.
- Turkey is a net importer of gas and oil, and has become increasingly dependent on natural gas from a pipelines that runs through the country.
- Turkey could improve its energy security by increasing utilization of its sizeable coal resources.
- Lignite gasifies well and the deep seams are good for UCG. However, many issues must be addressed, such as selecting the best regions and sites, identifying economic uses for the product gas, thin seams, high moisture. Therefore, some R&D activities must be done beforehand

Regarding UGG, TKI has completed a lab scale project and is conducting a feasibility study. These are:

1 - Research and analysis of underground coal gasifying in the laboratory environment

2 - Gasification of Turkish Lignite via Underground Coal Gasification (UCG)

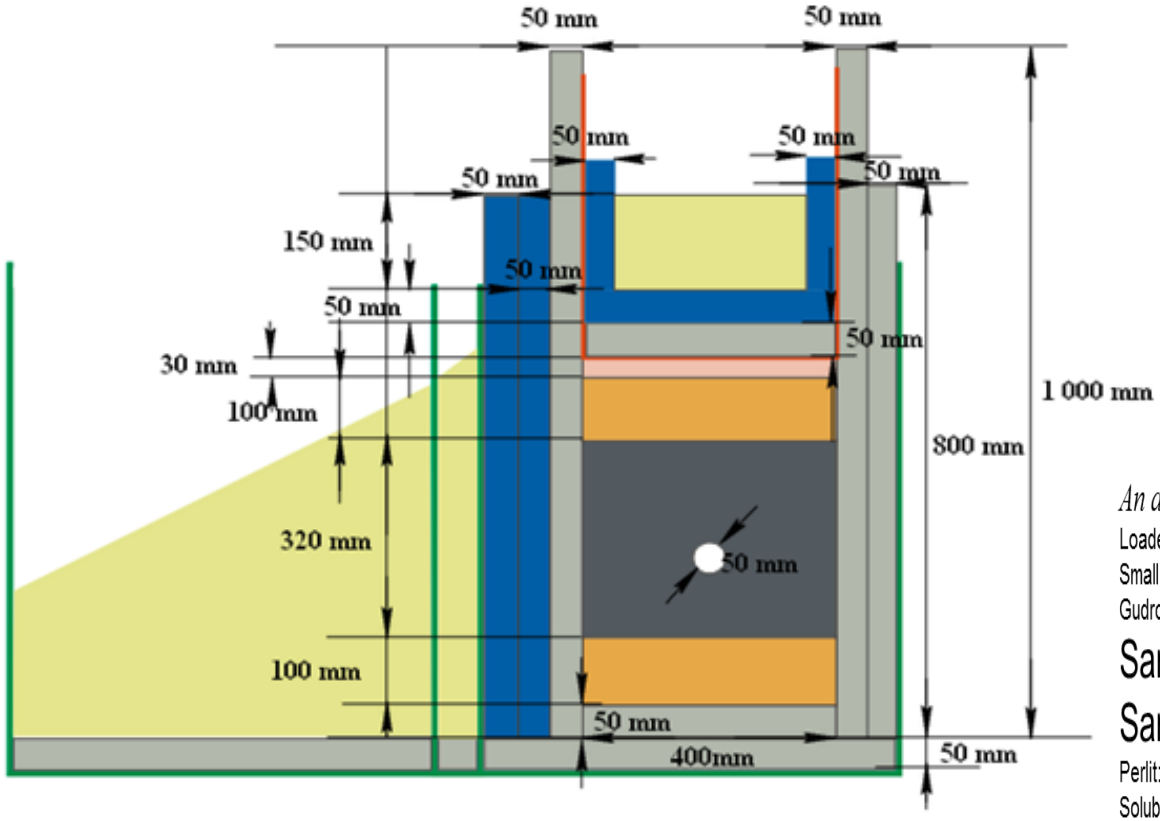
RESEARCH AND ANALYSIS OF UCG IN LABORATORY ENVIRONMENT

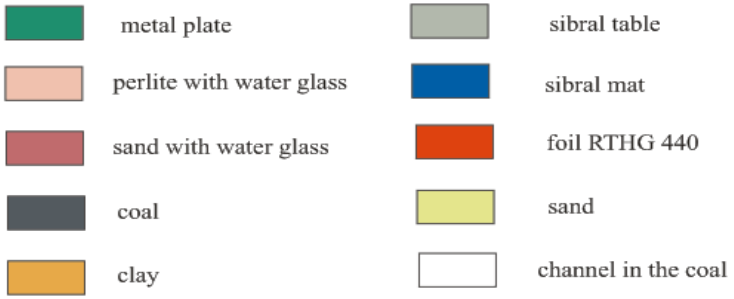
- The research was performed in cooperation with Kosice Technical University Faculty of Berg, (Slovaika)
- Aim of the research is to simulate UCG process in laboratory environment
- 1,5 ton of Soma region coal were used for the experiment
- Chracteristics of the coal
  - Calorific value……: 2625 kcal/kg
  - Fixed carbon (%)..: 17,76
  - Total moisture (%): 13,93
  - Ash (%)……: 35,32
  - Volatile matter (%): 32,99
- Samples were taken U/G coal mine in Soma and before haul to the surface, samples were sealed to prevent loss in moisture content and volatile matter
- There were two experiments carried out with the supplied coal

  Experiment 1. With drilling the gasification channel (channel model): a horizontal hole is drilled in the sample so that air/oxygen can pass through

  Experiment 2. Without drilling the gasification channel: In this case, no channel is drilled, but the required permeability of the coal massive was reached by its separation with pressure using liquid or gaseous media
- The research was completed in September, 2010

RESEARCH OF UNDERGROUND COAL GASIFYING IN THE LABORATORY ENVIRONMENT





An amount of material used

Loaded rough pieces of coal: 506 kg

Small pieces of coal and coal dust :70 kg

Gudron : 15 kg

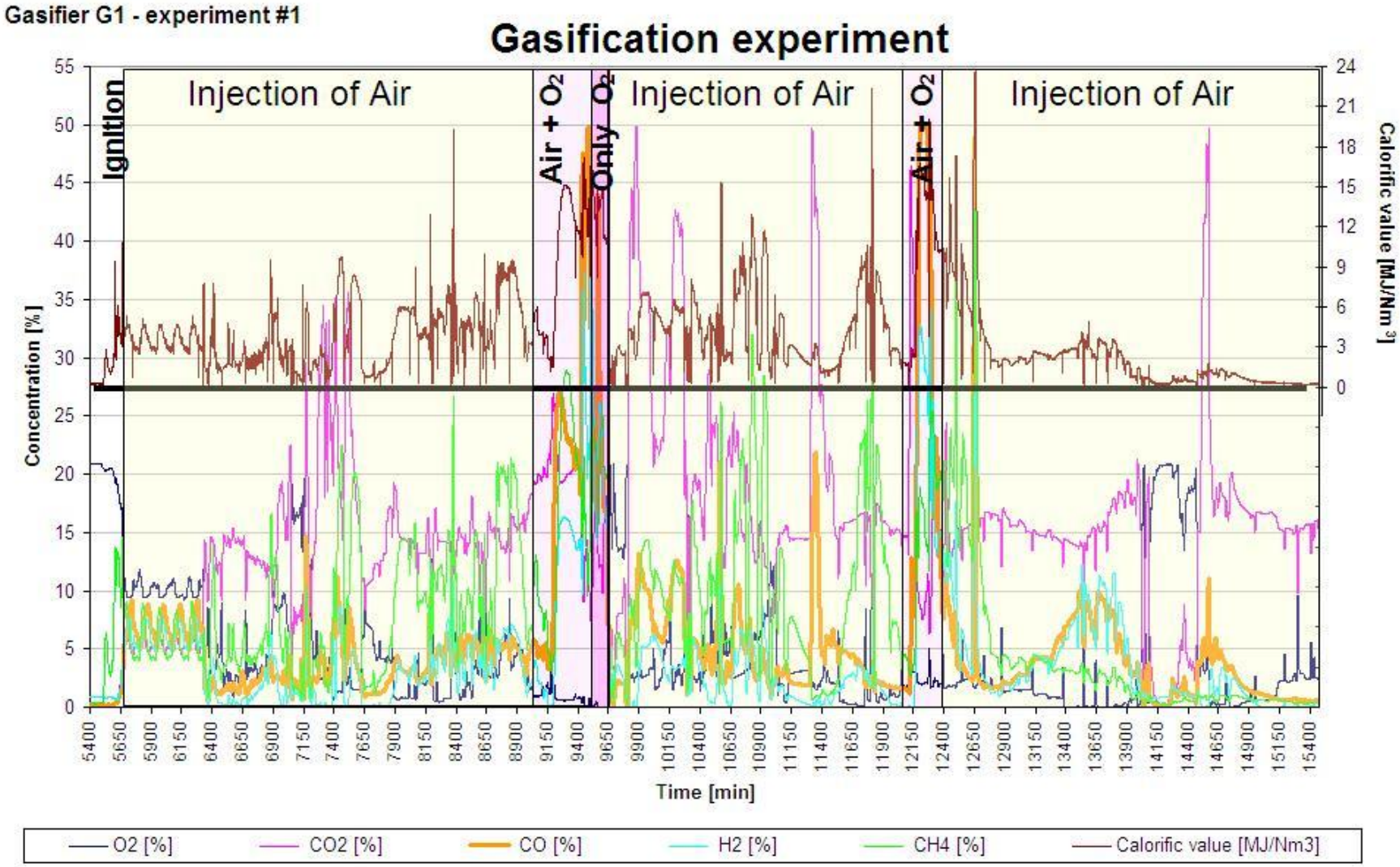
Sand above coal model: 304 kg

Sand from left site of coal model : 1780 kg

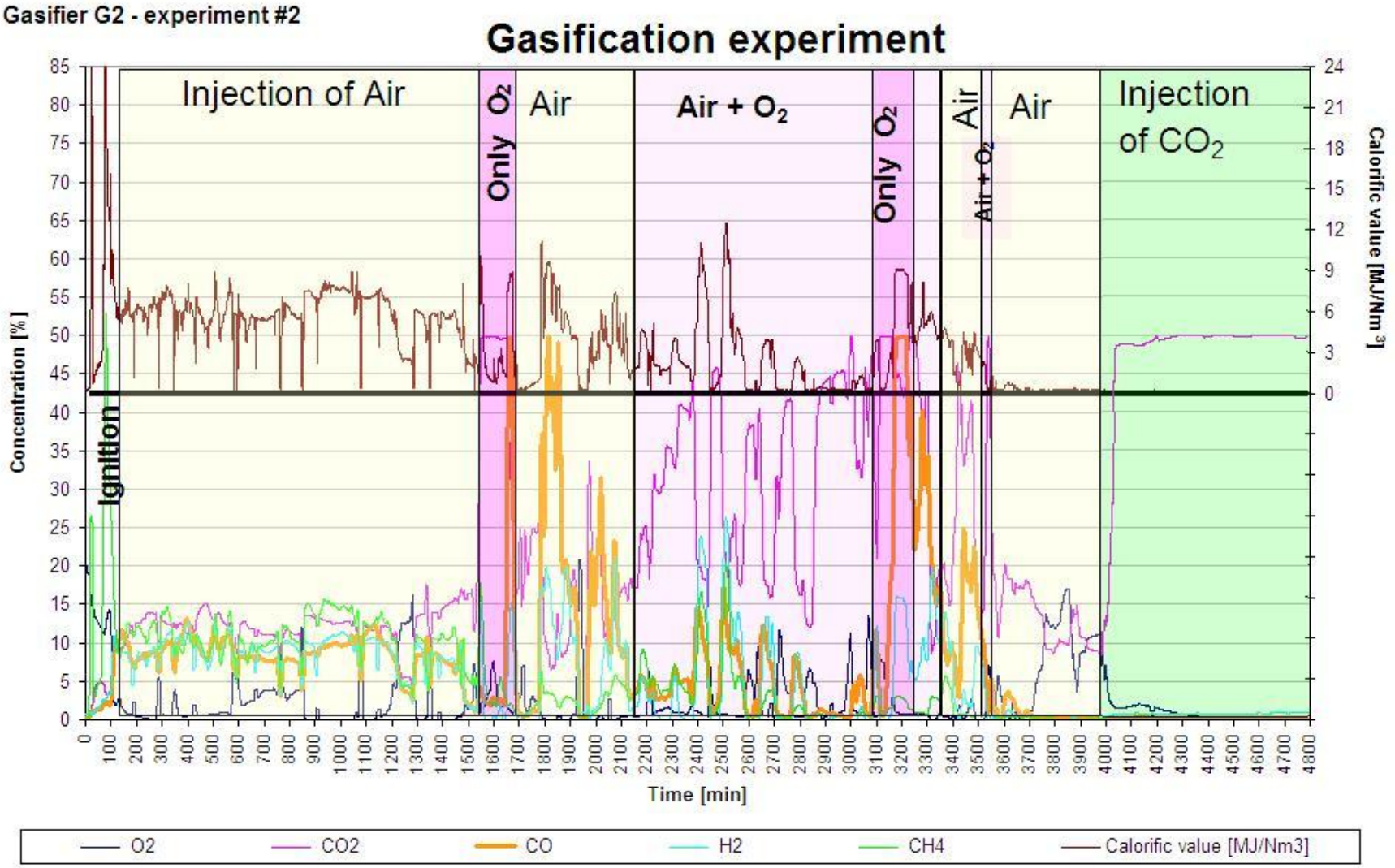
Perlit:18kg

Soluble (water) glass: 40l

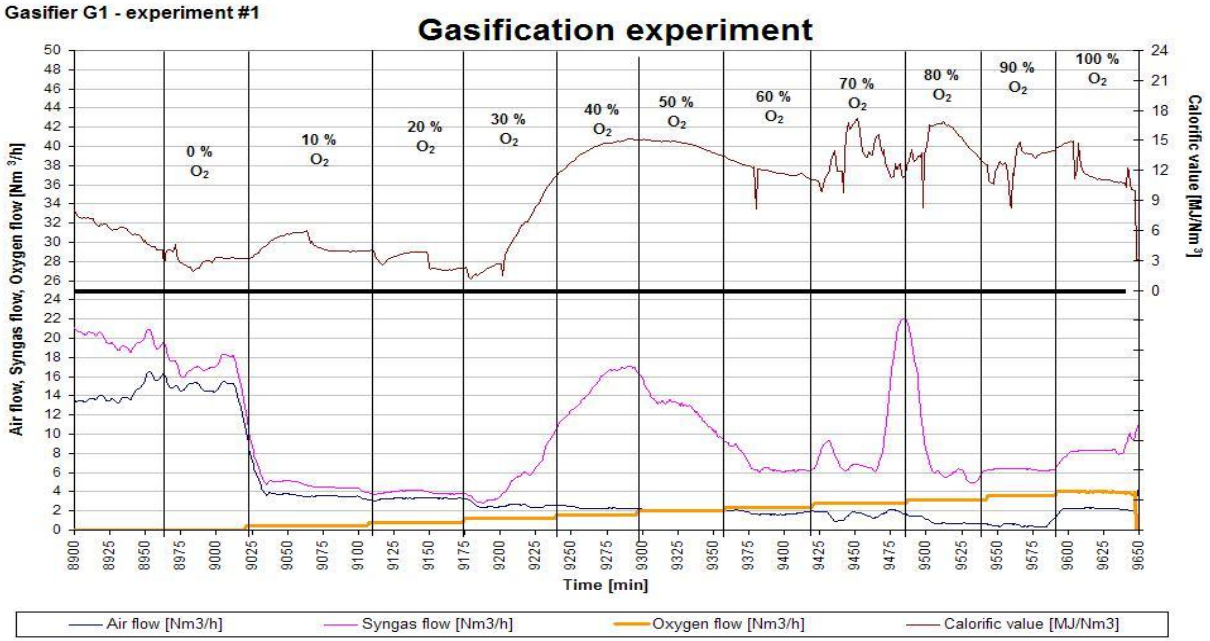
BEHAVIOUR OF THE MEASURED CONCENTRATION IN SYNGAS DURING EXPERIMENT 1 WITH DIVIDING INTO PARTITIONS WITH VARIOUS OXIDIZERS



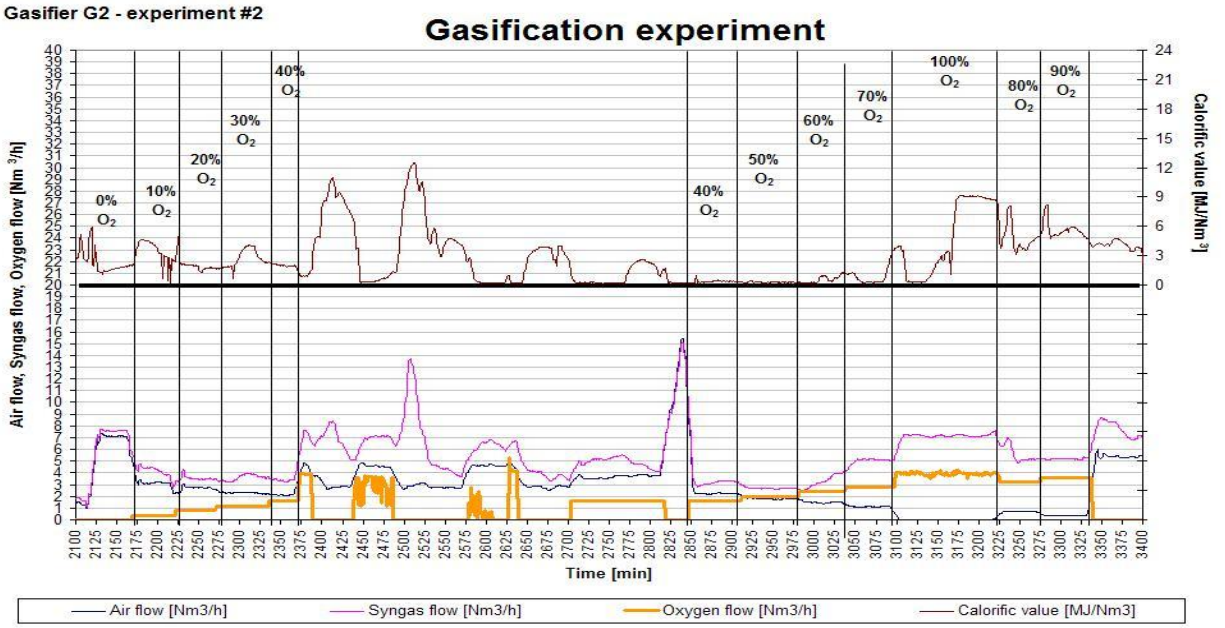
BEHAVIOUR OF THE MEASURED CONCENTRATION IN SYNGAS DURING EXPERIMENT 2 WITH DIVIDING INTO PARTITIONS WITH VARIOUS OXIDIZERS



Influence of the oxygen added to the oxidizer mixture during experiment



Behaviour of the increasing oxygen percentage in the oxidizer mixture during experiment



RESEARCH RESULTS OF UCG IN LABORATORY ENVIRONMENT

- For first experiment, the highest calorific value (16 - 17 MJ/Nm^3) of produced gas was achieved at 70% and 80% of the O_2 in the mixture with an air
- The first experiment showed that the used coal can be gasified with positive results (maximal calorific value of about 20 MJ/m^3)
- For second experiment, the highest long – term calorific value (9 MJ/Nm^3) of produced gas was achieved in gasification with 100 % O_2
- With the increasing temperature, the CO production increases
- The highest CO content in syngas can be reached only at high temperatures of about 1000°C
- Higher concentrations of gases CO, H_2, CH_4 were measured in the section with a higher calorific value.
- Drying of the coal did not influence gasification performance
- In the gasification, it is necessary to minimize the oxygen content in syngas. The more oxygen in SYNGAS, the less calorific value and the lower its quality
- The syngas volume flow is a linear dependence of the oxidizing mixture volume flow.
- it is possible to control the gasification velocity by regulating the volume flow of the oxidizing mixture.

FEASIBILITY STUDY OF UNDERGROUND COAL GASIFICATION (UCG) FOR TKI

- TKI signed an agreement with Lawrence Livermore National Laboratory (LLNL), DOE (Department of Energy) to carry out a feasibility study of UCG
- The agreement was signed in January, 2011 and will last 14 months
- The purpose of the agreement is to provide the Sponsor (TKI) with consultancy/advisory services regarding the selection and characterization of a site where TKI can establish an UCG plant

The Services consist of the following tasks:

- Development of a UCG program plan,
- Analyses to identify favorable regions and sites for an UCG plant by using the LLNL's "Sweet-Spot" analysis;
- Assistance with characterization of a selected site;
- Additional technical support including technical analyses, assessments,
- Project management and submission of the UCG Turkey Book, a report containing the results of the works, assessments, reviews and analysis made while performing the above-mentioned Services.

ACCOMPLISHED ACTIVITIES IN THE SCOPE OF UCG(UCG) FOR TKI FEASİBİLİTY PROJECT

- A Workshop of Underground Coal Gasification was organised between April 13-15th, 2011 with the participation of TKI Personnel, experts and academician
- Second activity with respect to the project is technical survey and jeological study of TKI Mine Sites, which was realised between July 16-22. The Survey was evaluated in a meeting headed by TKI General Director
- The information of coal characteristics, drilling logs, jeological survey etc. of 11 coal sites have been handed over LLNL
- In order to understand base and ceiling sustainabilities of coal seams, works regarding chemical and mineralogical tests have been carried out by TKI

COAL GASIFICATION VIA PLASMA APLICATION

- Plasma is ionized gas at high temperatures like 5000-30000 °C
- Ionization is separation of at least one electron from atom or molecole
- Beside spread application of plasma technology in various indusry fields, it is proven to use effectively for coal gasification by which high-quality synthesis gas (syngas) ($CO + H_2$) could be produced.
- There is a high humidity rate in the Turkish lignite known as low-grade fuel. For this reason, using the natural moisture in lignite is more senseable for plasma gasification technology

Advantages of coal plasma gasification:

- CO_2 concentration in gaseous products is higher than 12% in traditional gasification process of coal gasification while CO_2 concentration is no more than 3% in the process of coal plasma gasification under arc plasma condition
- Successful at gasification of low grade (high moisture) coal
- Near-zero SO_X, NO_X, VOC, and Hg emissions
- Easy to operate
- There is no sample preparation step
- Lower operating costs
- Lower slag

LAB SCALE PLASMA GASIFICATİON PROJECT

- TKI has had a contract with ANADOLU PLAZMA Company in Gazi Technopark to conduct lab scale coal gasification studies
- 1,5 and 3 Kw plasma gasifiers manufactured at which gasification experiments of high moisture content TKI coals have been carried out
- As seen in the table below, promising results have been achieved. Particularly, high hydrogen content from steam plasmatron is very important
- A patent has been obtained from Turkish Patent Institute for new steam gasification system
- It is planned that the contract will be extended as covering microvawe gasification

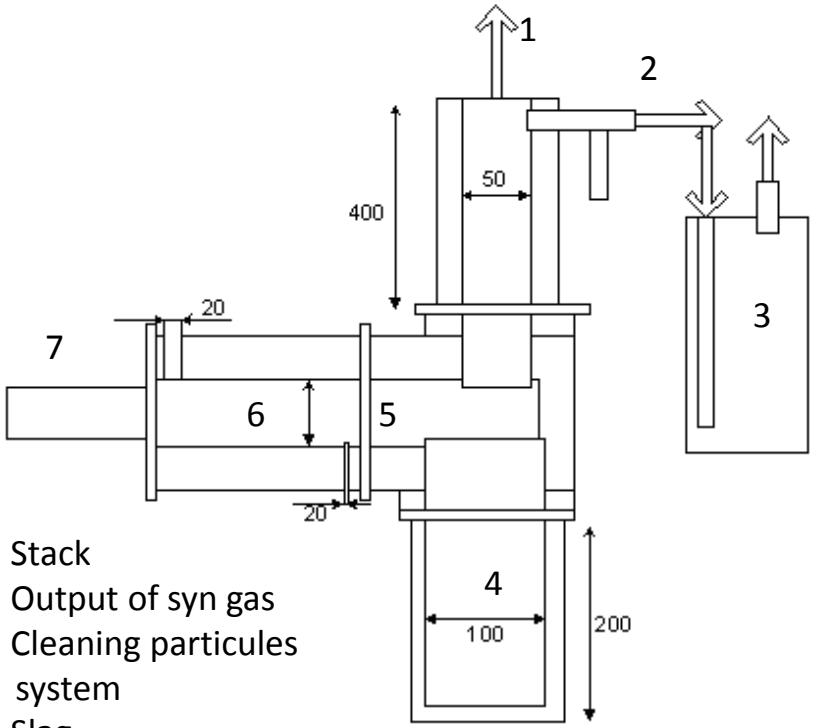
Gas chromatograhy (GC) results of steam plasmatron, air plasmatron and air plasmatron in the presence of steam

Gases	Steam plasmatron *	Air plasmatron **	Air plasmatron in the presence of steam ***
Hydrogen	81.47	1.85	26.10
Methane	6.95	0.05	0.38
Ethane	0.24	-	-
Ethylene	5.94	-	0.53
Carbondioxide	2.81	10.71	2.71
Butane	0.16	-	0.057
Nitrogen	0.98	86.0	70.06
Carbonmonoxide	1.45	1.45	0.16
Acetylene	-	0.02	-

* :Effect of steam plasma conditions on syn gas composition.
** :Determination of hydrogen ratio in the coal
*** :Effect of steam on air-plasma gasification of coal.

LAB SCALE PLASMA GASIFICATION PROJECT

Schematic drawing of the top part of the setup for coal gasification under plasma conditions



1. Stack
2. Output of syn gas
3. Cleaning particules system
4. Slag
5. Gas mixed chamber
6. Reactor
7. Plazmatron

A PICTURE FROM 3Kw PLASMA COAL GASIFICATION UNIT

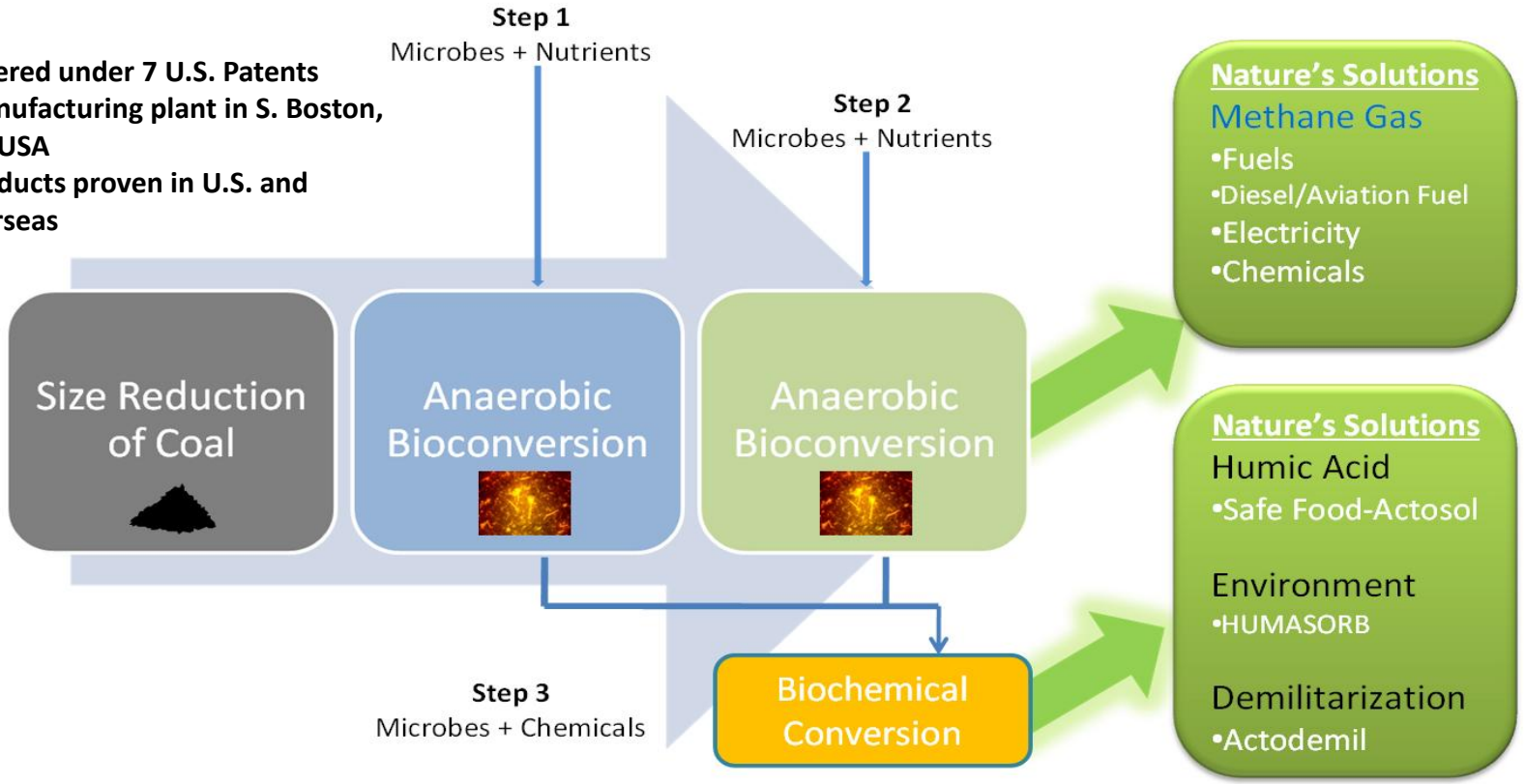
MicGAS Coal Biotechnology Project

- TKI signed an agreement with ARCTECH-USA for demonsration of Mic GAS Technology for application Turkish Lignite
- First of all, lab studies on Turkish Lignites at ARCTECH USA Labs
- Now pilot demonsrations are underway in Turkey

METHANE PRODUCTION BY COAL BIOTECHNOLOGY

- The MicGAS™ Process

Covered under 7 U.S. Patents
Manufacturing plant in S. Boston, VA, USA
Products proven in U.S. and overseas



Rationale

- Under anaerobic conditions natural microorganisms convert a variety of carbon containing materials into methane

LANDFILLS	RICE PADDIES
COAL MINES AND WASTE PILES	MUNICIPAL WASTEWATER
ANIMAL MANURES	LAKE BEDS

- Microorganisms utilize carbon for growth and produce biogas and byproducts

$C_{270}H_{240}N_3S_1O_{90}$ —MICROBES→ CH3COOH + other VFAs

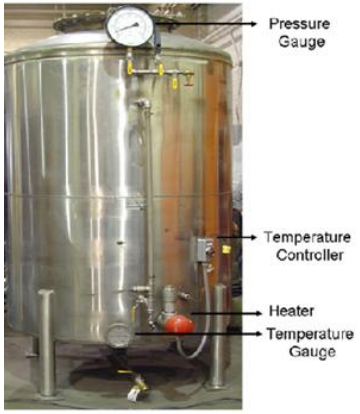
CH_3COOH —METHANOGENS→ CH4 + CO2

- Bioconversion is accomplished near ambient conditions, thus potentially economic approach of converting coal into clean fuels and byproducts
- MicGas™ Coal Biotechnology is applicable to all ranks of coal

MicGAS™ Mobile Pilot Unit Demonstration with Turkish Lignite at Techno Park, Ankara

-100 mesh ground coal slurry

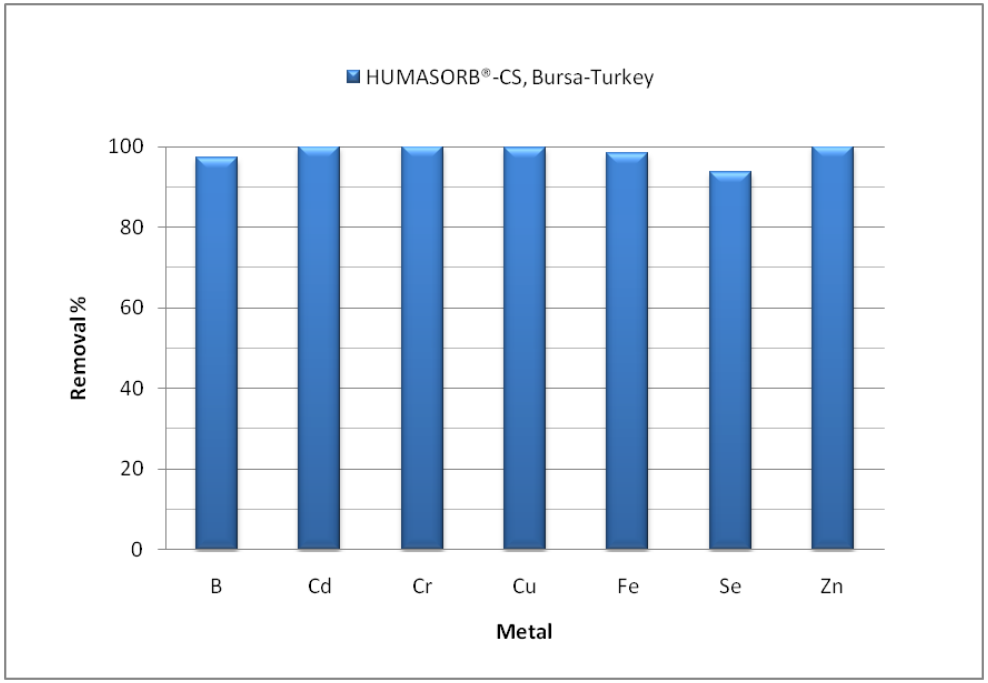
Nutrient medium



Concentrated Culture

Micas™ Mobile Pilot Unit Demonstration with Turkish Lignite at Techno Park, Gazi Univ., Ankara

Production of HUMASORB®-CS Beads from Humic Acid and Removal of Multiple Toxic Metals



Metal Removal by HUMASORB®-CS, Bursa-Turkey and USA (Initial = 10 ppm)

Actodemil™ Tests for Safe Destruction and Recycling of Explosives into Fertilizer, MKEK-Turkey

actosol® Organic Humic Fertilizer from Turkish Lignite Approved by Turkish Government

T.C.
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Toprak - Gübre ve Su Kaynakları Merkez Araştırma Enstitüsü Müdürlüğü
PK 5, 06172 Yenimahalle-Ankara
Tel: 0312-315 65 61-65 Faks. 0312-315 29 31

BİTKİ - ORGANİK GÜBRE LABORATUVARI ANALİZ RAPORU

Analysis Report of Plant- Organic Fertilizer Laboratory

İstek Kayıt No / Tarihi	04.08.2011
Rapor No	089
Rapor Tarihi	18.08.2011

Örneğin Adı	Bursa Con Humik Asit
Laborotuvar No	103
Organik Madde (%, 550 ^{0}C'de yanma kaybı, kuru maddede)	5,22
Toplam Humik Asit (W/W, %,TSE 5869)	19,53
Suda Çöz. Potasyum (K_2O, Fleymfotometrik, %)	5,47
pH (orj.)	12,31

Analiz Sorumlusu
Canize DEMEL
Ziraat Yüksek Mühendisi

Laboratuar Sorumlusu
Dr. Hesna OZCAN
Ziraat Yüksek Mühendisi

Analiz sonuçları yukarıda belirtilen numune(ler) için geçerlidir.
Bu rapor, TGSKMAE'nin yazılı izni olmadan kısmen kopyalanıp çoğaltılamaz. İmzasız ve mühürsüz raporlar geçersizdir.
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RESULTS OBTAINED FROM BIOTECHNOLOGY APPLICATION TO TURKISH LIGNITES

-Under Anaerobic Conditions, MicAn microbes successfully degraded Turkish lignite coal to acetic acid.

- MicAn microbes further converted acetic acid to biogas with more than 70% methane.

- Undegraded coal was further bio-converted to humic acid products for agriculture, environmental and military applications

-The Bioconversion was accomplished near ambient conditions, thus potentially economic approach of converting coal into clean fuels and byproducts

- Two sides are considering full scale implementation of Mic GAS Tehnology in Turkey

EQUIPMENTS OF R&D LABORATORY

	INSTRUMENT	BRAND-MODEL	DESCRIPTION
1	INDUCTIVELY COUPLED PLASMA OPTICAL EMISSION SPECTROMETRY	VARIAN ICP OES 710 ES	Used for the detection of trace elements. It is a type of emission spectroscopy determining characteristic of a particular element. Increased accuracy by eliminating spectral interferences, even with difficult samples
2	ATOMIC ABSORPTION SPECTROPHOTOMETER	VARIAN AAS SPECTRA A 240 ZEEMAN, SPECTRA A 240 FS FLAME	AA instrument includes flame and furnace system. It is a spectroanalytical procedure for the qualitative and quantitative determination of chemical elements
3	XRF SPECTROMETERS	BRUKER- S8 TİGER	It is used for determination of the chemical composition of many types of materials and wide range of elements; suitable for solid, liquid and powdered samples. It can also measure concentrations
4	FOURIER TRANSFORM INFRARED SPECTROPHOTOMETER	SHIMADZU FTIR - IR AFFINITY1	Identification of unknown chemicals . It is used to obtain an infrared spectrum of absorption, emission of a solid, liquid or gas. FTIR spectrometer simultaneously collects spectral data in a wide spectral range
5	UV-VIS SPECTROPHOTOMETER	SHIMADZU UV 1800	UV-VIS spectrophotometers shine visible or UV light onto a chemical, metal, or non-metal sample (usually a solution) and measure the amount of each component from the degree of absorption of the light
6	GAS CHROMATOGRAPHY	AGILENT GC	It analyzes any type of complex gas stream and hydrocarbon analyses
7	Micro-GC GAS ANALYZER	AGİLENT SRA A-3000	It analyzes any type of complex gas stream
8	BET SURFACE AREA, PORE SIZE, ADSORPTION INSTRUMENT	MICROMERITICS ASAP 2020	It produces BET surface area results using the classical helium void volume method, and also a pore size analyzer capable of measuring both adsorption and desorption isotherms in a few hours
9	MERCURY POROSIMETRY	MICROMERITICS AUTOPORE IV 9500	It characterizes a material's porosity by applying various levels of pressure to a sample immersed in mercury
10	GAS PYCNOMETER	MICROMERITICS ACCUPYC 1340	Measuring the absolute density and the volume of a rigid, solid material of simple geometry straight forward
11	DENSITY METER	ANTON PAAR	Measurement the density of liquid and gas samples
12	MERCURY ANALYZER	TELEDYNE LEEMAN LABS HYDRA – C	It measures direct analysis of total mercury of the solid or liquid samples
13	CHNS ELEMENTAL ANALYZER	LECO TRUSPEC	Determination of carbon, hydrogen, nitrogen and sulfur elements
14	CALORIMETER	LECO AC 600	Determination of the thermal value of coal sample
15	ASH FUSİON TESTER	LECO AF 700	It is used for measuring ash fusion temperature, including deformation point (DT), softening point (ST), hemisphere temperature (HT) and floating temperature. (FT) in coal ash

CONCLUSION

- Turkey has to utilize coal deposits, which are one of the most important energy resources of the country, effectively and environment friendly,
- Therefore, Turkish Coal Enterprises (TKI) has undertaken several gasification R&D projects that are in form of feasibility study, lab scale and pilot scale and established an admirable R&D laboratory,
- So far, some encouraging results have been achieved from the projects and TKI also hopes that better and beneficial results will be reached at,
- TKI expects that R&D projects will lead to innovations so that Turkey will have commercial gasification plants in medium and long period that solves energy problem considerably.

THANK YOU FOR YOUR ATTENTION!