

出國報告（出國類別：其他）

參加IPCC-28研討會發表研究論文出國 報告

服務機關：核能研究所

姓名職稱：陳銘宏 副研發師

派赴國家：美國

出國期間：100年9月10日~100年9月16日

報告日期：100年10月18日

摘要

本次會議主題為第二十八屆匹茲堡國際煤碳研討會。

基於目前政府積極推動之減碳相關政策，本次派員赴美國參加 **28th International Pittsburgh Coal Conference (IPCC)**，發表會議論文，除可瞭解世界各國目前於潔淨能源之發展現況，亦可與相關領域之專業人士交流相關知識。

IPCC 之議題包括捕碳/封存計畫近況、燃燒與氣化等重要議題，為獲知目前減碳議題發展最新狀況之重要年度會議。

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一、目的

核能研究所(以下稱本所)目前正積極進行能源相關計畫，包括「減碳政策評估與淨碳技術發展」、「淨碳系統模擬分析技術開發」與「潔淨燃料工廠虛擬整合工程模擬平台研發」等。為瞭解目前國際於相關研究議題之發展現況，本次公差主要為參加 28th International Pittsburgh Coal Conference (IPCC)，並發表研究論文。

第 28 屆年會於 2011 年 9 月 12 – 15 日於美國賓州匹茲堡市(Pittsburgh)舉行，會議主題包括捕碳/封存計畫近況、燃燒與氣化等重要議題，為獲知目前減碳議題發展最新狀況之重要年度會議。

為了在潔淨能源技術之研究議題上進行交流，有世界各先進研究團隊參與此會議，包括 NETL, DOE, Cogentrix, LTI, CAER, CONSOL Energy Inc., NICE, LLC, CAER 等。故本所派員參與此會議為交流與驗證專業技術之良機。

二、過 程

(一) 公差行程

本次公差自民國 100 年 9 月 10 號至 9 月 16 號日止，共計 7 天(圖 II-1)。



圖 II-1：公差行程示意圖

- 9 月 10 日(星期六) 自台灣桃園機場出發
- 9 月 10 日(星期六) 抵達美國紐約紐華克機場
- 9 月 11 日(星期日) 自紐約紐華克機場轉機至匹茲堡市
- 9 月 12 日(星期一) ~ 9 月 14 日(星期三) 註冊，出席第 28 屆 IPCC 會議，發表論文
- 9 月 15 日(星期四) 由匹茲堡出發，於鳳凰城轉機，再至洛杉磯轉機
- 9 月 16 日(星期五) 返抵台灣桃園機場

(二) 第 28 屆匹茲堡淨煤國際會議(International Pittsburgh Coal Conference, IPCC)

第 28 屆年會於 2011 年 9 月 12 - 15 日於美國賓州匹茲堡市(Pittsburgh)舉行(圖 II-2 ~ II-7)，會議主題包括捕碳/封存計畫近況、燃燒與氣化等重要議題，為獲知目前減碳議題發展最新狀況之重要年度會議。

為了在潔淨能源技術之研究議題上進行交流，有世界各先進研究團隊參與此會議，包括 NETL, DOE, Cogentrix, LTI, CAER, CONSOL Energy Inc., NICE, LLC, CAER 等約四百人參加此會議。

IPCC-28 之議程如表 II-1 所示。每天早上先進行全體會議(Plenary Session)，此全體會議各有三場 keynote 演講。接著是早上一段口頭論文發表，下午則是安排兩段口頭論文發表，每一段論文發表共有六個場次同時進行。海報論文發表安排在 9 月 14(星期四)晚上進行。



圖 II-2 舉辦會議之 Westin 飯店



圖 II-3 匹茲堡市區景象



圖 II-4 IPCC-28 會場外觀



圖 II-5 連接飯店與會場之天橋



圖 II-6 911 十週年紀念活動



圖 II-7 匹茲堡市夜景

表 II-1：IPCC-28 之議程

PRELIMINARY PROGRAM SCHEDULE						
Monday, September 12, 2011						
11:00-16:00	Technical Tour - Cardinal Plant					
15:00-19:00	Registration - Room 306					
18:30-20:30	Reception - Rooftop Terrace					
Tuesday, September 13, 2011						
7:00-17:00	Registration - Room 306					
8:00-8:20	Opening Ceremony - Ballroom					
8:20-10:05	Plenary Session - Ballroom					
10:05-10:20	Coffee Break					
ROOM	301	302	303	304	305	310/311
	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
10:20-12:00	Major CCS Demo Projects: Financing of CCT and CCS Projects	Gasification: General Session - 1	Coal-Derived Products: General - 1	Carbon Management: CO ₂ Capture - Sorbents - 1	Combustion: Emission Controls	Mining
12:00-13:30	Conference Luncheon - Ballroom					
	Session 7	Session 8	Session 9	Session 10	Session 11	Session 12
13:30-15:10	Major CCS Demo Projects: Financial Risk Management Strategies for CCT	Gasification: Economics	Coal-Derived Products: General - 2	Carbon Management: CO ₂ Capture - Sorbents - 2	Combustion: Oxy-Combustion - 1	Coal Science: Beneficiation
15:10-15:25	Coffee Break					
	Session 13	Session 14	Session 15	Session 16	Session 17	Session 18
15:25-17:25	Major CCS Demo Projects: Insurance and Risk Management Strategies for	Gasification: Modeling - 1	Coal-Derived Products: General - 3	Carbon Management: CO ₂ Capture - Sorbents - 3	Combustion: Oxy-Combustion - 2	Coal Science: Coal Geochemistry
18:00-21:00	Gateway Clipper Dinner Cruise					
Wednesday, September 14, 2011						
7:00-17:00	Registration - Room 306					
8:20-10:05	Plenary Session - Ballroom					
10:05-10:20	Coffee Break					
ROOM	301	302	303	304	305	310/311
	Session 19	Session 20	Session 21	Session 22	Session 23	Session 24
10:20-12:00	Major CCS Demonstration Projects: General - 1	Gasification: Low Rank coal	Coal-Derived Products: General - 4	Carbon Management: CCS and GHG Abatement - 1	Combustion: Combustion Studies - 1	Coal Science: Coal Geology
12:00-13:30	Conference Luncheon - Ballroom					
	Session 25	Session 26	Session 27	Session 28	Session 29	Session 30
13:30-15:10	Major CCS Demonstration Projects: General - 2	Gasification: Coal & Biomass	Coal-Derived Products: General - 5	Carbon Management: SECARB-ED CCS Training Session - 1	Combustion: Chemical Looping - 1	Coal Science: Coal Science - 1
15:10-15:25	Coffee Break					
	Session 31	Session 32	Session 33	Session 34	Session 35	Session 36
15:25-17:25	Major CCS Demonstration Projects: General - 3	Gasification: Modeling - 2	Coal-Derived Products: General - 6	Carbon Management: SECARB-ED CCS Training Session - 2	Combustion: Chemical Looping - 2	Coal Science: Coal Science - 2
18:00-21:00	Poster Session - Room 319/320/321					
Thursday, September 15, 2011						
7:00-17:00	Registration - Room 306					
8:20-10:05	Plenary Session - Ballroom					
10:05-10:20	Coffee Break					
ROOM	301	302	303	304	305	310/311
	Session 37	Session 38	Session 39	Session 40	Session 41	Session 42
10:20-12:00	Major CCS Demonstration Projects: General - 4	Gasification: Fundamentals	Gasification: General - 2	Carbon Management: CCS and GHG Abatement - 2	Combustion: Combustion Studies - 2	Sustainability and Environment: General - 1
12:00-13:30	Awards Luncheon - Ballroom					
	Session 43	Session 44	Session 45	Session 46	Session 47	Session 48
13:30-15:10	Major CCS Demonstration Projects: General - 5	Gasification: Gas Cleanup	Gasification: General - 3	Carbon Management: CCS and GHG Abatement - 3	Carbon Management: CO ₂ Geologic Sequestration - Coal	Sustainability and Environment: General - 2
15:10-15:25	Coffee Break					
	Session 49	Session 50	Session 51	Session 52	Session 53	Session 54
15:25-17:25	Major CCS Demonstration Projects: General - 6	Gasification: Underground Coal Gasification	Gasification: General - 4	Carbon Management: CCS and GHG Abatement - 4	Carbon Management: CO ₂ Capture - Solvents	Sustainability and Environment: General - 3
18:00-20:00	Advisory Board Meeting					

本次大會之議程共計分七項領域進行，各領域之主題摘要如下：

2011 Sessions and Topics

1. Combustion

Session Chair: [John Wheeldon](#), EPRI and [Evan Granite](#), U.S. DOE/NETL

- Industrial Applications, Economics, and Environmental Issues
- Advance Pulverized Coal Combustion Technologies (Supercritical, Fluidized Bed, Etc.)
- Novel Technologies (Oxyfuel, Chemical Looping, Etc)
- Flue Gas Clean Up
- Science And Modeling
- Materials, Instrumentation, and Controls
- Turbines (Steams)

2. Gasification

Session Chairs: [Massood Ramezan](#), Leonardo Technologies, Inc. (LTI), and [Jenny Tennant](#), U.S.

DOE/NETL

- Industrial Applications, Economics, and Environmental Issues
- Underground Coal Gasification (UCG)
- Synthesis Gas Cleanup
- Gasification Science and Modeling
- Novel Gasification Technologies and Concepts
- Co-Gasification of Coal and Biomass

3. Sustainability and Environment

Session Chair: [Jim Hower](#), University of Kentucky, CAER

- Energy Production and Water Use - Conservation and Recycle
- Life Cycle Analysis (LCA) of Energy Production Systems

- Energy Production Impact on the Environment
- Energy Sustainability - Efficiency and Conversion to Reduce GHG
- GHG: Inventory Protocol, Legal and Regulatory Considerations, Credits

4. Carbon Management

Session Chairs: [Richard Winschel](#), CONSOL Energy Inc. and

[Steve Carpenter](#), Advanced Resources International, Inc.

- Pre-Combustion Capture
- Post-Combustion Capture
- CO2 Sequestration (Monitoring, Mitigation, and Verification; Storage: Depleted Oil/Gas Reservoirs, Aquifers, Basalt, Coal Bed Methane)
- Transportation Infrastructure and Issues
- Legal and Regulatory Issues
- Carbon Footprint Comparison: CTX (DCL/ICL), Petroleum

5. Coal-Derived Products

Session Chairs: [Belma Demirel](#), Rentech, Inc., [Ke Liu](#), National Institute of Clean & Low-carbon

Energy (NICE), [Rachid Oukaci](#), Energy Technology Partners, LLC, and [Xin Xiao](#), Savannah River

National Laboratory

- Coal-To-Liquids, CTL (Direct Liquefaction, Fischer-Tropsch, Methanol-To-Gasoline, Etc.)
- Substitute Natural Gas (SNG)
- Hydrogen Production
- Syngas Utilization (Gas Turbines, Fuel Cells)
- Chemicals/Materials
- Coal Utilization By-Products (Ash, Fertilizers, Etc.)
- Jet Fuel

6. Coal Science

Session Chair: [Jim Hower](#), University of Kentucky, CAER, and [Leslie "Jingle" Ruppert](#), US

Geological Survey

- Chemistry
- Geoscience/Coal Resources
- Trace Elements/Emission
- Processing
- Coal Preparation

7. Major CCS Demonstration Projects

Session Chairs: [Gary Stiegel](#), U.S. DOE/NETL and [Thomas Sarkus](#), U.S. DOE/NETL

- Updates on existing clean coal major demonstration projects (IGCC, SCPC, USC, Oxy-combustion, etc.)
- Status of current clean coal development projects with carbon capture and storage
- Industrial large-scale demonstrations of carbon capture and storage project

筆者於 9 月 15 日(星期四)搭機離開美國，於 9 月 16 日(星期五)返抵台灣桃園機場，結束本次公差行程。

會後亦公告下屆會議之時間，將於 101 年 10 月 15-18 日於相同地點舉行。

三、心得

本次公差主要乃是參加第 28 屆 International Pittsburgh Coal Conference (IPCC-28)，發表研究論文。以下摘錄部份相關研究論文。

1. Plenary Sessions

會議進行方式首先進行全體會議(Plenary Session)，並安排各三場 keynote 演講，本屆應邀之講員如下：

PLENARY SPEAKERS

TUESDAY, SEPTEMBER 13, 2011

Energy Production/Policy Speakers

Charles McConnell

Chief Operating Officer, Fossil Energy

Department of Energy, USA

Thomas J. Bonner

President

Cogentrix Energy, LLC, USA

Steve Herman

Managing Director

Energy Capital Partners, USA

WEDNESDAY, SEPTEMBER 14, 2011

International Issues

Yuzhou Zhang

CEO

Shenhua Group, CHINA

Steve Orlins

President

National Committee on US-China Relations, USA

Sami Demirbilek

CEO

Ciner Group, TURKEY

THURSDAY, SEPTEMBER 15, 2011

Environmental Issues

Anthony Cugini

Director

Department of Energy, USA

Steven Winberg

Vice President, R & D

CONSOL Energy Inc., USA

Frank Princotta

Director, Air Pollution Prevention and Control

Division, USEPA, USA

(1) Energy Production/Policy

9月13日早上之演講議題為「能源產出/策略(Energy Production/Policy)」；講者分別來自政府單位，研究機構與產業界。首位演講者 **Charles McConnel**，為美國化石能源部門(Fossil Energy Department of Energy)之首席運營長(Chief Operating Officer)(圖 III.1-1)，其講題為“Fossil energy in a Carbon Constrained World”(圖 III.1-2)。演講重點摘錄如圖 III.1-3 ~ III.1-9 所示，其演講涵蓋以下議題：

- DOE Strategic Plan (圖 III. 1-3)
 - Transform our Energy Systems
 - Science and Engineering Enterprise
 - Secure our Nation
 - Management and Operational Excellence
- Fossil Energy Portfolio (圖 III. 1-4)
- Oil and Gas (圖 III. 1-5)
- CO₂-Enhanced Oil recovery (圖 III. 1-6)
- International Collaboration (圖 III. 1-7)
- Return of Investment (圖 III. 1-8)
- Conclusion (圖 III. 1-9)
 - Competition for Global Resources
 - Global Environmental Trends and Policies
 - Technology Demonstrations
 - Commercial Scale
 - Create a Compelling Choice for Fossil Energy That is Game-Changing and Sustainable

第二位演講者 **Thomas J. Bonner**，為 Cogentrix Energy, LLC 之總裁，其演講之題目為“Consideration of Coal, other Fuels, and Technology in Developing and Operating a U. S. Generation Portfolio”(圖 III.1-10)。Cogentrix 設立於 1983 年，自 1985 年起已建立 18 座電廠，裝置容量超過 5,000 MW。其中包括 9 座燃煤電廠。其報告中提及目前促使產業發展之動力為燃氣成本與運煤成本之競爭，目前現存之電廠技術將會限制燃煤電廠修建之機會，另外，近況不佳之經濟情況將導致嚴重之電能短缺 (圖 III.1.11 ~ III.1.27)。其內容包括以下議題：

- Customer Objectives(圖 III.1.16)
 - Investor owned utilities, municipals and coops - build v. buy
 - Regulatory restrictions
 - Accounting and reporting
- Reserve Margins and Operating Environment(圖 III.1.17 ~ III.1.20)
- Regulation (圖 III.1.21 ~ III.1.24)
- Availability of Financing (圖 III.1.25)

- What's the Future for Coal in the Generation Mix in the U.S.? (圖 III.1.26)
 - Long term relationship between natural gas and coal pricing
 - Electric rate regulation and cost recovery
- Summarization (圖 III.1.27)

(2) International Issues

9月14日早上之演講議題為「國際議題(International Issue)」；講者為大陸神華集團總裁 **Yuzhou Zhang**，講題為：「The Clean Coal Conversion & Utilization Technologies in Shenhua and China」(圖 III.1-28)。神華公司設立於1995年，為目前中國最大之產煤公司以及全球最大煤供應商。其整合多項業務包括礦業、動力、鐵路、港務以及煤轉換為液態及化學原料等技術。並指出提升煤炭使用效率為未來降低二氧化碳之有效方式。而將生質物混入煤炭中使用能夠更進一步降低二氧化碳排放(圖 III.1-29 ~ III.1-30)。其演講議題包括：

- CO₂ reduction (圖 III.1-31 ~ III.1-33)
- Clean coal conversion (圖 III.1-34)
- Technology Portfolio of Shenhua & NICE (圖 III.1-35)
- Major Clean Coal Conversion Demo Projects in China (圖 III.1-36 ~ III.1-41)
- Coal conversion process analysis (圖 III.1-42 ~ III.1-45)
- Concluding Remarks (圖 III.1-46)

2. Technical Paper Sessions

IPCC-28 之論文發表接在全體演講之後，早上一個時段，下午兩個時段，同時有六個場次之口頭論文發表進行，每場安排約 5~6 篇論文之發表。議題分為七項：(1) Major CCS Demo Projects, (2) Gasification, (3) Coal-Derived Products, (4) Carbon Management, (5) Combustion, (6) Mining, (7) Coal Science。筆者參與主題與業務內容較相關之論文發表，摘錄部份論文如下。

論文 # 2-4 (圖 III.2-1 ~ III.2-12)

此篇論文由 NETL 之 **Stephen E. Zitney** 發表，演講主題為 Advanced Virtual Energy Simulation Training and Research: IGCC with CO₂ Capture Power Plant。主要介紹其建立之 AVESTAR Center 之模擬技術及訓練課程及研究主題。其模擬器宣稱可模擬 IGCC 整廠之動態響應，且具有三維即時互動能力。訓練課程則包括 IGCC、氣化程序以及 Combined Cycle 操作等。

論文 # 14-1 (圖 III.2-13 ~ III.2-24)

此篇論文由 University of Utah 之 **Kevin J. Whitty** 發表，演講主題為 Pressurized Entrained Flow

Coal Gasifier Performance: A Parametric Study。主要是針對加壓-吹氧式挾帶床氣化爐進行參數測試，測試之參數為氧氣壓降(停滯時間)、氧/煤比及壓力對於出口溫度、產氣成份之影響。該氣化爐為介於實驗室等級以及商轉等級之中等規格爐體，可在接近工業用條件進行測試，且易於取得結果進行分析。

論文 # 14-2 (圖 III.2-25 ~ III.2-33)

此篇論文由澳洲 CSIRO 之 **Daniel G. Roberts** 發表，演講主題為 **Experimental and Modeling Studies of Pressurized Coal Gasification Behavior**。CSIRO 之研究方向主要為澳洲煤之氣化行為與高溫 char-steam 之反應速率探討。模型主要用以確定氣化子模型當中部份化學成份之形成細部機制。採用之爐體為加壓式挾帶床氣化爐，在稀釋環境下進行測試，但保持適當之氧/碳比率。另外將 char-steam 反應獨立出來探討，實驗參數包括氧/碳比率與停滯時間對氣化結果之影響。

論文 # 14-3 (圖 III.2-34 ~ III.2-45)

此篇論文由 NETL 之 **Job S. Kasuel** 發表，演講主題為 **Steady-State Modeling of a Single-Stage, Downward-Firing, Entrained-Flow Gasifier**。主要是針對挾帶床氣化爐建立包括細部化學反應機制之穩態模型，並嘗試延伸至動態模型。其化學反應機制共包含 4 條異相反應與 6 條同相反應。另外，其模型亦包含一 heuristic recirculation 模型，用以評估迴流現象對於初始流場之影響。其爐體壁面熱傳模式採用熱對流模式進行計算，而非其它文獻中以假設之線性溫度分佈的方式。採用之求解器為 Aspen Customer Modeler (ACM)。其模型計算出之結果與文獻值、工業結果頗為一致。

論文 # 14-5 (圖 III.2-46 ~ III.2-54)

此篇論文由澳洲 CSIRO 之 **Daniel G. Roberts** 發表，演講主題為 **Using Fundamental Data to Model Entrained Flow Gasification: Impacts of Coal Type on Gasifier Performance**。主要是將其先前發展之 2 維軸對稱模型應用至實際氣化爐之構型與操作條件中。其子模型包括去揮發化模型、異相反應模型、揮發物與可燃氣之氧化反應、同相之水氣轉化反應、熱對流與熱輻射模型等。並選用四組不同之氧/碳比率進行測試。

論文 # 32-1 (圖 III.2-55 ~ III.2-59)

此篇論文由 West Virginia University 之 **Kiran Chaudhari** 發表，演講主題為 **Development of Advanced Gasification Kinetics Models for CFD (and Process Simulation) Codes**。主要是整合現有之各種化學反應機制子模型於其自行建立之模組當中。透過其自行建立之 GUI 介面，可將目前現在之各式化學反應機制導入其模組當中。在設定相關參數後，即可導入目前各式之商用軟體當中進行運算。

論文 # 32-2 (圖 III.3-1 ~ III.3-24)

此篇論文為本所與 University of New Orleans 之王亭教授合作之成果，由王亭教授發表，演講主題為 Numerical Analysis of Gasification Performance via Finite-Rate Model in a Cross-Type Two-Stage Gasifier。此研究主要乃是建立三維之 cross-type，兩級式氣化爐模型。分析之參數包括氧/煤比、水煤漿濃度、第一/第二級導入燃料分佈之影響。

論文 # 32-3 (圖 III.2-60 ~ III.2-72)

此篇論文由 University of New Orleans 之王亭教授發表，演講主題為 Development of a Devolatilization Model in Multi-Phase Simulation of a Mild Gasifier with a Draft Tube。此研究主要乃是提出 IMGCC 之概念式系統設計，其中 M 表示 Mild 之 IGCC 系統，主要是在除硫系統中假設可在高溫情況下進行。此種 Mild gasifier 包含流體化之現象，故需採用 E-E 模型進行計算。初步結果顯示此概念設計是可行的，但細部設計需要再進一步修正。

3. Poster Sessions

IPCC-28 之 Poster session 場次安排在 9 月 14 日晚間舉行，主題同樣包含前述各領域，其論文篇數如下：

- (1) Combustion：6 篇 (去年 17 篇)
- (2) Gasification：19 篇 (去年 8 篇)
- (3) Sustainability and Environment：9 篇(去年 11 篇)
- (4) Carbon Management：10 篇 (去年 11 篇)
- (5) Coal-Derived Products：6 篇 (去年 17 篇)
- (6) Coal Science：19 篇 (去年 28 篇)

與前一年度比較，在 gasification 部份之論文篇數大幅增加，部份海報展示摘要如下(圖 III.4-1 ~ III.4-6)。

主要心得分述如下：

1. 原先於相關研究議題之瞭解只局限於研究文獻，藉由參加此國際會議可藉由演講提供大方向之瞭解，而參加論文發表會議則能夠獲知較細部之研究現況，對於往後進行相關研究能夠提出相關建議，對於核心業務之進行有相當大之助益。
2. 除了解歐美各國之發展現況外，本次公差亦獲知，目前大陸方面對於淨煤技術之發展現

況，且由於大陸當局為追求經濟成長，使其雖具有煤礦產出能力亦成為化石能源之輸入國；另外再加上金磚四國中之印度對於能源之需求，將進一步推升我國化石能源取得之困難度，故我國在潔淨能源與淨煤技術之研究為目前最重要之發展議題之一。另外，於神華集團主席 Yu Zhuo Zhang 之演講中提及，提高煤炭之使用效率為未來降低二氧化碳之最有效辦法，此觀點與目前本組進行之運轉參數測試以尋找提高煤炭氣化效能之目標一致；另外也提到生質燃料與煤炭混燒可進一步降低二氧化碳排放，此與本年度投稿於國際會議之探討項目相關。故本組目前進行之研究方向基本上與國際間認知之主要發展方向一致。

3. 本組所發表之論文場次中，與會人員曾提及是否曾驗證吾人提出之模型，然目前唯有 NETL 之報告內容可供成份比對，而溫度與爐內細部現象則無資料可供比對；因此在提出模型之結果前，須先以實驗數據驗證，再進行後續之參數分析。然目前於實驗結果獲得之困難度使得模型驗證只能以部份報告內容進行比對，往後若有機會能夠獲得較完整且細部之實驗結果，對於模型之發展將有重大之助益。
4. 在海報發表場次中，有學者建議吾人於關鍵組件分析時，亦同時須搭配完整之程序分析，方能避免見樹不見林之現象。故本組可與系統程序分析小組進行進一步交流互相了解目前最新發展現況。
5. 在本次公差之前，筆者主辦之委託案遇到無觸媒水氣轉化反應參數難以獲得之困境，而在此會議當中同樣有學者提出此議題，並表示約只有 5% 之研究是符合需求之設定條件，因此找尋與氣化條件一致之反應參數，為改善模型可靠度之重點工作之一。
6. 本組進行關鍵組件分析時，為求模型之完整性，考慮約 8~10 條同相與異相之化學反應式，而此會議當中則有部份研究乃是僅考慮單一異相化學反應式之現象進行探討，例如煤焦-水蒸氣或二氧化碳之單一反應，此結果可納入目前建立之化學反應模型之反應參數

資料庫當中，藉由與其它文獻參數進行比較，並選取較適當之參數值用於模型之測試中。

7. 在氣化場次發表中部份作者無法出席，故筆者抽空前往參加 Major CCS Demonstration Projects 之發表。在聆聽該場次之發表中發現，報告人除說明目前技術層面之發展現況外，其計畫案都會建立一套 Revenue Model 以評估其商業價值。由於目前美國之經濟困境，故相關計畫推動所需之資金將由政府出資逐漸轉為民間資金。因此計畫之投資報酬率之重要性不亞於技術面之發展。本所在設計示範設施過程中，除技術層面之考量外，亦可將商業運轉之方向列入考慮，以提高其經濟價值。
8. 王亭教授提出之 IMGCC 之概念，若發展成功，將可提高目前燃煤電廠之可用率，唯其前提乃是高溫除硫技術需能配合。此研究預估需十年左右之研究時程，且比較偏重學術層面之研究。唯其建立之多相流、E-E 模式下之揮發模型與暫態分析能力為目前本組較不熟悉之部份，故往後可於此議題上與王教授交流，可提高本組於氣化爐分析能力之完整性。

四、建議事項

本所目前正積極進行能源相關計畫，包括「減碳政策評估與淨碳技術發展」、「淨碳系統模擬分析技術開發」與「潔淨燃料工廠虛擬整合工程模擬平台研發」等。為瞭解目前國際於相關研究議題之發展現況，本次公差主要為參加 International Pittsburgh Coal Conference (IPCC)，發表研究論文。第 28 屆年會於美國賓州匹茲堡市(Pittsburgh)舉行，會議主題包括捕碳/封存計畫近況、燃燒與氣化等重要議題，為獲知目前減碳議題發展最新狀況之重要年度會議。本次公差行程之建議事項如下：

- (一)氣化爐內之反應機制仍充滿許多不確定性，尚需要進一步之基礎研究，除採用 CFD 模擬分析外，尚需搭配實驗結果以充份驗證反應機制，故實驗結果之取得為後續在發展上之重要議題。
- (二)在針對關鍵組件進行分析時，尚需搭配完整之程序分析，方能對氣化程序之整體概念有較完整之瞭解。
- (三)目前氣化爐內之水氣轉化反應之數據主要是在有觸媒之情況下，而實際氣化過程則無觸媒參與其中，故找尋無觸媒情況下之反應參數，並導入目前建立之模型當中，為進一步改善計算結果之重要工作之一。
- (四)本次會議有數篇研究僅針對煤焦與水氣/二氧化碳之單一反應進行分析，此分析結果可用於調整目前所建立之異相化學反應機制。
- (五)本次會議當中有許多論文將商業模型納入其設計參數之考量當中，並強調唯有將設計領往具有商業潛力之方向，才有進一步發展之價值，建議本所可投入在此議題上，以提高未來欲建立之氣化程序之商業價值。
- (六)綜合考量目前國際上於氣化分析之現況，建議明年可採用 finite-rate，或 finite-rate/eddy-dissipation 之模型進行後續之操作參數分析工作。
- (七)目前合作之紐奧良大學研究團隊已具有多相流與暫態行為分析能力，建議明年度之傳輸式氣化爐/循環式流體化床氣化爐之研究可委託其進行。

五、附 錄

(一) 本屆大會議程

(二) Plenary Session 相關圖片

(三) Technical Paper Session 相關圖片

(四) 發表之論文投影片

(五) Poster Session 相關圖片

(一) 本屆大會議程



TWENTY - EIGHTH ANNUAL INTERNATIONAL
PITTSBURGH COAL CONFERENCE

PRELIMINARY PROGRAM

COAL - ENERGY, ENVIRONMENT AND
SUSTAINABLE DEVELOPMENT



September 12 - 15, 2011

Pittsburgh, PA USA

The David L. Lawrence Convention Center



Sponsors



北京低碳清洁能源研究所
NATIONAL INSTITUTE OF CLEAN AND LOW-CARBON ENERGY

Hosted By:
University of Pittsburgh
Swanson School of Engineering



GENERAL INFORMATION

2011 PCC

The University of Pittsburgh, along with the Advisory Board and Participating Organizations, invites you to attend the **Twenty-Eighth Annual International Pittsburgh Coal Conference**, September 12 - 15, 2011 at the David L. Lawrence Convention Center in Pittsburgh, PA. The opening ceremony will take place on Monday, September 12, 2011. Over 300 technical papers, including posters, will be presented throughout the conference. Technical topics cover a wide spectrum of energy and environmental issues and technologies related to coal and its by-products. For detailed information on technical sessions, papers, and speakers, turn to the Technical Program in this brochure.

TECHNICAL TOUR:

Cardinal Plant

Monday, September 12, 2011

11:00 - Bus Pickup from the Westin Hotel

12:15 - Arrive at plant

2:45 - Depart from plant

4:00 - Arrive at the Westin Hotel

Cost: \$50 (Lunch included)

Cardinal Plant is located along the Ohio River south of Brilliant Ohio and represents the first ever alliance between an investor owned utility (AEP) and a member owned utility (Buckeye Power). Buckeye Power is an organization of 25 rural electric cooperatives.

Cardinal Units 1 and 2, put into service in 1967, utilize a double reheat supercritical cycle, are directly cooled from the Ohio River and have a net rating of 600 MW. Cardinal Unit 3, put into service in 1977, utilizes a single reheat supercritical cycle, employs a hyperbolic cooling tower and has a net rating of 630 MW. This unit is also the first and only coal-fired boiler in the U.S. that exhausts through the cooling tower.

All three Units burn high-sulfur eastern bituminous coal and consume about 4.5 Million tons per year. In the early 2000's, the three Units were retrofitted with Selective Catalytic Reduction systems and subsequently with wet FGD. The FGD systems on Units 1 and 2 are in service and that on Unit 3 is under construction.

The Pittsburgh Coal Conference tour will include a description of all 3 Units, and a tour of the Unit 3 facility. There will be an opportunity for questions and answers with the plant staff following the tour.

ACCOMMODATIONS

**The Westin Hotel
1000 Penn Avenue
Pittsburgh, PA 15222**

Recommended accommodations for the 2011 PCC are at the Westin Hotel in downtown Pittsburgh. The Westin Hotel is connected by a skywalk to the David L. Lawrence Convention Center. The conference rate is \$165 per night in either a single or double room. There is an additional \$10 charge per person for a room with more than two people.

Please note this group rate is available only until August 12, 2011 and is subject to availability.

To receive this discounted conference rate, please make your reservations directly with the hotel using the link provided on our website.

GATEWAY CLIPPER DINNER CRUISE

Tuesday, September 13, 2011

18:00 - 18:30 - Boarding at the dock
by the Convention Center

18:30 - 21:00 - Dinner and cruising

21:00 - Return to hotel

Please join us for a dinner cruise on Pittsburgh's three rivers! Back by popular demand, this cruise is complimentary for conference attendees, but there is a charge of \$45 to bring a spouse or friend. However, you **MUST** RSVP to the PCC secretary to be included on the cruise. For more information and to RSVP, please visit our website.

PITT AWARD

The Pitt Award for Innovation in Coal was founded by the Chemical and Petroleum Engineering Department, University of Pittsburgh in 1983 through industrial support. Since 1992, it has been fully funded by CONSOL Energy Inc. The Pitt Award, as well as the best paper and poster awards, will be presented at the Awards Luncheon, Thursday, September 15 at 12:00.

GENERAL INFORMATION

CONFERENCE OVERVIEW

MONDAY, SEPTEMBER 12, 2011

Technical Tour	11:00 - 16:00
Registration	15:00 - 19:00
Reception	18:30 - 20:30

TUESDAY, SEPTEMBER 13, 2011

Registration	07:00 - 17:00
Opening Ceremony	08:00 - 08:20
Plenary Session – 1	08:20 - 10:05
Concurrent Tech. Sessions	10:20 - 12:00
Conference Luncheon	12:00 - 13:30
Concurrent Tech. Sessions	13:30 - 17:25
Gateway Clipper Dinner Cruise	18:00 - 21:00

WEDNESDAY, SEPTEMBER 14, 2011

Registration	07:00 - 17:00
Plenary Session – 2	08:20 - 10:05
Concurrent Tech. Sessions	10:20 - 12:00
Conference Luncheon	12:00 - 13:30
Concurrent Tech. Sessions	13:30 - 17:25
Poster Session	18:00 - 21:00

THURSDAY, SEPTEMBER 15, 2011

Registration	07:00 - 17:00
Plenary Session – 3	08:20 - 10:05
Concurrent Tech. Sessions	10:20 - 12:00
Awards Luncheon	12:00 - 13:30
Concurrent Tech. Sessions	13:30 - 17:25
Advisory Board Meeting	18:00 - 20:00

PLENARY SPEAKERS

TUESDAY, SEPTEMBER 13, 2011

Energy Production/Policy Speakers

Charles McConnell

Chief Operating Officer, Fossil Energy
Department of Energy, USA

Thomas J. Bonner

President
Cogentrix Energy, LLC, USA

Steve Herman

Managing Director
Energy Capital Partners, USA

WEDNESDAY, SEPTEMBER 14, 2011

International Issues

Yuzhou Zhang

CEO
Shenhua Group, CHINA

Steve Orlins

President
National Committee on US-China Relations, USA

Sami Demirbilek

CEO
Ciner Group, TURKEY

THURSDAY, SEPTEMBER 15, 2011

Environmental Issues

Anthony Cugini

Director
Department of Energy, USA

Steven Winberg

Vice President, R & D
CONSOL Energy Inc., USA

Frank Princotta

Director, Air Pollution Prevention and Control
Division, USEPA, USA

TECHNICAL PROGRAM

16:25 - **Extension of Reversible Carbon Dioxide Binding by Frustrated Lewis Pairs to New Phosphine and Amine Bases**, Robert L. Thompson, URS/DOE/NETL; Krishnan Damodaran, University of Pittsburgh, USA

16:45 - **First Principles and Classical Simulations of Ionic Liquids for Carbon Dioxide Capture**, Bo Zhang, J. Karl Johnson, University of Pittsburgh/DOE/NETL, USA

17:05 - **Using Novel Phase Change Solvents or High Molecular Weight Silicone Oil for the Pre-Combustion Capture of CO₂**, Matthew B. Miller, Robert M. Enick, University of Pittsburgh; David R. Luebke, DOE/NETL, USA

SESSION 54

SUSTAINABILITY AND ENVIRONMENT: GENERAL – 3

Jim Hower

15:25 - **The 3rd Assessment of Pennsylvania's ACT 54 – Protecting Structures, Land and Water Supplies from Underground Coal Mine Subsidence Damages, 2003 to 2008**, Anthony Iannacchione, Stephen J. Tonsor, William Harbert, University of Pittsburgh, USA

15:45 - **Projection of Australian Coal Production – Comparisons of Four Models**, Mikael Höök, Uppsala University, SWEDEN; Steve Mohr, Geoffrey Evans, The University of Newcastle; Gavid Mudd, University of New South Wales, AUSTRALIA

16:05 - **EPA Mandatory Reporting Rule and PSD BACT: Effects on Coal, ECBM and Lessons Learned from the First Year of Implementation**, Steven M. Carpenter, Advanced Resources International, Inc., USA

16:25 - **Minimizing Water Discharge and Maximizing Re-Use in Coal Combustion and Conversion Processes**, William A. Shaw, HPD, a Veolia Water Solutions & Technologies Company, USA

16:45 - **Quality and Quantity of Flowback Water in Marcellus Shale Gas Play**, Elise Barbot, Radisav Vidic, University of Pittsburgh, USA

17:05 - **The Activity of the Water Gas Shift Reaction over Copper Based Catalysts with Different Support**, Dong-Hyeok Choi, Joong Beom Lee, Tae Hyoung Eom, Jeom In Baek, Seong Jegarl, Seug-Ran Yang, Keun Woo Park, Chong Kul Ryu, KEPSCO Research Institute, KOREA

POSTER SESSIONS Wednesday, September 14, 2011 18:00 – 21:00

POSTER SESSION 1 COMBUSTION

P1-1 - **Attrition as a Key Parameter for Evaluation of Usefulness of the Oxygen Carriers in Chemical Looping Process**, Ewelina Ksepko, Marek Sciazko, Olaf Piotrowski, Institute for Chemical Processing of Coal, POLAND

P1-2 - **Simultaneous NO_x/SO_x Removal by Ammonia Gas Excited by Atmospheric Plasma**, Shinji Kambara, Yukio Hayakawa, Kazuhiro Kumabe, Hiroshi Moritomi, Gifu University; Megumi Masui, Actree Corporation, JAPAN

P1-3 - **Application of Sewage Sludge Ashes in Chemical Looping Combustion of Solid and Gaseous Fuels**, Ewelina Ksepko, Grzegorz Labojko, Marek Sciazko, Institute for Chemical Processing of Coal, POLAND

P1-4 - **W2 Wobble Plate Prime Mover – Sealed Unit**, Jerry Willis, Admiral Air, Inc., USA

P1-5 - **Morphologies and X-ray Parameters of Inertinite-rich and Vitrinite-rich South African Bituminous Coal Chars**, Enette Louw, Gareth D. Mitchell, Jonathan P. Mathews, The Pennsylvania State University, USA

P1-6 - **Fluidised Bed Combustion of Brown Coal with Different Ash Content**, Osipov Pavel, Ryzhkov Alexander, Remenuk Anastasia, Ural Federal University, RUSSIA; Chernyavskiy Nikolay, Dulienko Sergei, Coal Energy Technology Institute of NAS of Ukraine, UKRAINE

POSTER SESSION 2 GASIFICATION

P2-1 - **The Design and Operational Behaviour of a Laboratory Scale Fixed-Bed Gasifier**, Frikkie Conradi, FB Waanders, North West University, SOUTH AFRICA

P2-2 - **Analyses of an Entrained-Bed Coal Gasifier Using a CFD Model Coupled with Chemical Reaction Kinetics**, Tsung Leo Jiang, Tai-Ping Wu, National Cheng Kung University; Ming-Hong Chen, Po-Chung Chen, Yau-Pin Chyou, Institute of Nuclear Energy Research Atomic Energy Council, TAIWAN

P2-3 - **Process Modeling of H₂S Removal from Brazilian Coal Gasification Syngas with MDEA**, Michael Crocetta, Thiago Fernandes de Aquino, Rui de Carvalho Junior, Brazilian Coal Mining Association/DOE/NETL; David Miller, Juan Morinelly, DOE/NETL, USA

P2-4 - **Comparison Study on CO₂-Gasification Reactivity of Different Chars**, Liwei Ren, Jianli Yang, Institute of Coal Chemistry, Chinese Academy of Sciences; Feng Gao, Taiyuan University of Technology, CHINA

P2-5 - **Model-Free Determination of Char-CO₂ Gasification Kinetics from Thermogravimetric Experiments**, Thinesh Vittee, University of the Witwatersrand, SOUTH AFRICA

P2-6 - **Progress of High Concentration Coal Water Slurry (CWS) Preparation Technology from Low Rank Coals and Lignite for CWS Gasification**, Baoqing Li, State Key Lab of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences; Feng He, Yulin Western Coal Technology Research Center, CHINA

P2-7 - **Application of Brown Coal Pyrolysis Tars in Black Coal Flotation**, Peter Fecko, Eva Pertile, Monika Podesvova, Josip Isek, Konstantin Babic, Lukas Koval, Lukas Pjura, Tien Pham Duc, VŠB – TU Ostrava; Josef Vales, Jaroslav Kusy, Brown Coal Research Institute, CZECH REPUBLIC

P2-8 - **Investigation of Gasification Behavior of Turkish Lignite in a Fluidized Bubbling Bed Gasifier**, Ayşe Tarakçıoğlu, Selahattin Anaç, Ömer Sezgin, Mustafa Zıypak, Vedat Mıhladı, Zeki Olgun, Abdullah Akça, Turkish Coal Enterprises (TKİ), TURKEY

P2-9 - **Design of an Atmospheric Bubbling Fluidized Bed for Co-Gasification of Coal and Paper Sludge**, Giovanna de Simone, Stefano Cordiner, Vincenzo Mulone, University of Rome "Tor Vergata", ITALY

P2-10 - **The Resource Utilization of Water Hyacinth by Co-Gasification with Coal**, Haifeng Liu, Qiang Zhang, Jianliang Xu, Xueli Chen, Xin Gong, East China University of Science and Technology, CHINA

P2-11 - **Effect of Bed Diffusion and Operating Parameters on Char Combustion in the Context of Underground Coal Gasification**, Ganesh A Samdani, Shauvik De, Sanjay Mahajani, Anuradda Ganesh, Indian Institute of Technology Bombay, Mumbai; Preeti Aghalayam, Indian Institute of

Technology Madras, Chennai; Sapru R. K., Mathur D. K., UCG Group, IRS, ONGC, INDIA

P2-12 - **Kinetic Studies of CO₂ Gasification in the Context of Underground Coal Gasification**, Ramesh Naidu Mandapati, Sateesh Daggupati, Naresh Hanchate, Sanjay Mahajani, Anuradda Ganesh, Indian Institute of Technology Bombay, Mumbai; Preeti Aghalayam, Indian Institute of Technology Madras, Chennai; Sapru R. K., Pal A.K., UCG Group, IRS, ONGC, INDIA

P2-13 - **Development and Application of Entrained-flow Coal Gasification Technology of ECUST**, Xin Gong, Jianliang Xu, Xueli Chen, Zhenhua Dai, Haifeng Liu, East China University of Science and Technology, CHINA

P2-14 - **Autothermal Reforming of Methane to Syngas Over Y₂O₃-Modified Ni γ -Al₂O₃ Catalysts**, Yizhuo Han, Yisheng Tan, Qingde Zhang, State Key Laboratory of Coal Conversion, Institute of Coal Chemistry, Chinese Academy of Sciences; Laizhi Sun, Graduate University of Chinese Academy of Sciences, CHINA

P2-15 - **Methane Reforming with Carbon Dioxide Over Nanostructured CO-Ni Catalysts**, N.V. Shikina, Z.R. Ismagilov, S.A. Yashnik, V.V. Kuznetsov, I.Z. Ismagilov, Borekov Institute of Catalysis SB RAS, RUSSIA; G.B. Aldashukurova, Z. A. Mansurov, Institute for Problems in Combustion of the Kazakh Committee of Science, KAZAKHSTAN

P2-16 - **Methane Reforming with Carbon Dioxide Over Nickel-Uranium Catalysts**, Z.R. Ismagilov, S.V. Lazareva, N.V. Shikina, V.V. Kuznetsov, M.A. Kerzhentsev, Borekov Institute of Catalysis of the Siberian Branch of the RAS, RUSSIA

P2-17 - **New Technologies for Monitoring UCG**, R. J. Mellors, X. Yang, S. Hunter, J. Wagoner, W. Foxall, D. Camp, S. J. Friedmann, Lawrence Livermore National Laboratory, USA

P2-18 - **A Study on Mass Transfer Coefficients in Underground Coal Gasification Cavities**, Sateesh Daggupati, Ramesh N. Mandapati, Sanjay M. Mahajani, Preeti Aghalayam, Naresh D. Hanchate, Anuradda Ganesh, IIT Bombay; Mathur D.K., Sharma R.K., IRS, ONGC, INDIA

P2-19 - **Mitigating Environmental Risk of UCG Project by Detail Studies of its Geology & Hydrogeology**, Pankaj Bhuyan, D.K. Mathur, R.P. Singh, A. Kumar, M.M. Dwivedi, UCG group, IRS, Oil and Natural Gas Corporation Ltd. (ONGC), INDIA

POSTER SESSION 3

SUSTAINABILITY AND ENVIRONMENT

P3-1 - **Fotoelectrochemical Properties of Thick Films from in Natura Pyrite**, Michael Peterson, Márcio Antônio Fiori, Universidade do Extremo Sul Catarinense; Adilson Oliveira da Silva, Formula Indústria Química do Brasil, BRAZIL

P3-2 - **A CUBIC MILE OF OIL: Realities and Options for Averting the Looming Global Energy Crisis**, Ripudaman Malhotra, SRI International, USA

P3-3 - **Impact of Underground Exploitation in Romania to Civil Constructions**, Chirilă Danut, University of Petrosani, ROMANIA

P3-4 - **Quartz in Thermal Coals of India: Its Measurement, Abundance and Impact in Power Plant and Environment**, Anup Kumar Bandopadhyay, Shobha Kumari, Rawesh Kumar, J K Pandey, Central Institute of Mining and Fuel Research, INDIA

P3-5 - **Integrated Solar Combined Cycle System to Achieve Near-Zero Emissions of Pollutants and**

TECHNICAL PROGRAM

16:15 - **The Medicine Bow Industrial Gasification and Liquefaction Project --- Project Update**, Robert Kelly, Jon Doyle, DKRW Advanced Fuels LLC, USA

16:40 - **Building a Cleantech USA "The New U.S. Synthetic Fuel Industry"**, H. H. Graves, USA Synthetic Fuel Corporation, USA

SESSION 32 GASIFICATION: MODELING - 2

Kristin Gerdes and Mehrdad Shahnam

15:25 - **Development of Advanced Gasification Kinetics Models for CFD (and Process Simulation) Codes**, Kiran Chaudhari, Richard Turton, West Virginia University; Chris Guenther, Mehrdad Shahnam, Ronald W. Breault, DOE/NETL; Aytekin Gel, ALPEMI Consulting, LLC; Philip Nicoletti, Tingwen Li, URS/DOE/NETL, USA

15:45 - **Numerical Analysis of Gasification Performance via Finite-Rate Model in a Cross-Type Two-Stage Gasifier**, Yau-Pin Chyou, Yan-Tsan Luan, Institute of Nuclear Research, Atomic Energy Council, TAIWAN; Ting Wang, University of New Orleans, USA

16:05 - **Development of a Devolatilization Model in Multi-Phase Simulation of a Mild Gasifier with a Draft Tube**, Jobaidur R. Khan, Ting Wang, University of New Orleans, USA

16:25 - **Numerical Simulation of coal Gasification in OMB Coal Gasifier**, Jianliang Xu, Xueli Chen, Zhenhua Dai, Haifeng Liu, Xin Gong, East China University of Science and Technology, CHINA

16:45 - **A Low-Dimensional Model for Detailed Simulation of Coal Gasification Systems**, James C. Sutherland, Naveen Punati, Babak Goshayeshi, University of Utah, USA

17:05 - **Studies on Spalling of Indian Coal in the Context of Underground Coal Gasification**, Sminu Bhaskaran, Sanjay Mahajani, Anuradda Ganesh, Indian Institute of Technology Bombay, Mumbai; Preeti Aghalayam, Indian Institute of Technology Madras, Chennai; Sapru R. K., Mathur D. K., UCG Group, IRS, ONGC, INDIA

SESSION 33 COAL-DERIVED PRODUCTS: GENERAL - 6

Belma Demirel and Steve Xiao

15:25 - **The Effects of Catalytic Additives on the Reactivity of Metallurgical Coke under CO₂ Atmosphere**, J.H. Choi, E.J. Kim, W.J. Lee, I.K. Suh, Raw Material Research Group of POSCO, KOREA

15:45 - **Studies on the Effect of High Temperature Carbonization Up to 2400°C on Coke Property from Tertiary Coal of North Eastern Region of India**, Ujjal Bhattacharjee, Atulya Bhattacharjya, Central Institute of Mining & Fuel Research, INDIA

16:05 - **Scavenging of Hazardous Organic Pollutants from Aqueous Waste Using Activated Carbon Prepared from Indian Coal**, Shripal Singh, Pragma Patil, Central Institute of Mining and Fuel Research, INDIA

16:25 - **The Possibility of Utilization of Carbon Black from Pyrolysis of Municipal Waste**, Dagmar Juchelková, Helena Raclavská, Adela Cizkova, Ondrej Zajonc, VSB-Technical University of Ostrava, CZECH REPUBLIC

16:45 - **Closure Turf: A New Approach to Coal Ash Closures**, Lindsey Agricola, Agru; Mike Ayers, Jose Urrutia, ClosureTurf, USA

17:05 - **Rapid Coal Pyrolysis to Acetylene in Multi-Stage Thermal Plasma Reactor**, Yi Cheng, Binhang Yan,

Tsinghua University; Cliff Y. Guo, Xuan Li, Changning Wu, National Institute of Clean-and-low-carbon Energy, CHINA

SESSION 34 CARBON MANAGEMENT: SECARB-ED CCS TRAINING SESSION - 2

Jack Pashin and Steve Carpenter

15:25 - **Water in Carbon Capture and Sequestration: Challenges and Opportunities**, James W. Castle, John H. Rodgers, Jr., John R. Wagner, Clemson University; Gerald R. Hill, Southern States Energy Board, USA

15:45 - **Clean Coal Technology Development and its Impact on the Energy Industry in the Southeastern United States**, Jack Pashin, Geological Survey of Alabama, USA

16:05 - **CO₂ Sequestration in Unmineable Coal with Enhanced Coal Bed Methane Recovery: The Marshall County Project**, James E. Locke, Richard A. Winschel, CONSOL Energy Inc.; Richard A. Bajura, Thomas H. Wilson, Hema J. Siritwardane, Henry Rauch, Douglas Patchen, Shahab D. Mohaghegh, West Virginia University; Arthur W. Wells, DOE/NETL, USA

16:25 - **China Coal and Carbon Capture and Storage (CCS)**, Timothy R Carr, West Virginia University, USA

16:45 - **Public Outreach and CCS: A Critical Analysis**, Brad Kelley, Nino S. Ripepi, Virginia Center for Coal and Energy Research at Virginia Tech, USA

SESSION 35 COMBUSTION: CHEMICAL LOOPING - 2

John Wheelodon and Evan Granite

15:25 - **Alstom's Calcium Oxide Chemical Looping Prototype, Program Update**, Herbert E. Andrus, Jr., John H. Chiu, Paul R. Thibeault, Carl D. Edberg, Alstom Power Inc.; Bruce Lani, DOE/NETL, USA

15:45 - **Iron Based Chemical Looping Processes Developed at The Ohio State University**, Deepak Sridhar, Liang Zeng, Andrew Tong, Rae Kim, Zhenchao Sun, Siwei Luo, Liang-Shih Fan, The Ohio State University, USA

16:05 - **Comparative Investigation on Chemical Looping Combustion of Coal-Derived Synthesis Gas Containing H₂S Over Supported Bimetallic Fe₂O₃-MnO₂ and Fe₂O₃-CuO Oxygen Carriers**, Ewelina Ksepko, Marek Sciazko, Institute for Chemical Processing of Coal, POLAND; Hanjing Tian, Thomas Simonyi, Parsons; Ranjani V. Siritwardane, DOE/NETL, USA

16:25 - **Chemical Looping with Oxygen Uncoupling: Exploring Opportunities by Process Modeling and Interpretation of Experimental Data**, JoAnn S. Lighty, Asad H. Sahir, Adel F. Sarofim, University of Utah, USA

16:45 - **Modeling, Simulation and Advanced Controls for Prototype Chemical Looping Process**, Abhinaya Joshi, Jie Luo, Xinhong Lou, Carl Neuschaefer, Alstom Power Inc., USA

17:05 - **Study the Effects of Hydration on the CO₂ Adsorption Capacity of Calcium-Based Sorbents with Density Functional Theory Calculation**, Siwei Luo, Fuchen Yu, L.-S. Fan, The Ohio State University, USA

SESSION 36 COAL SCIENCE: COAL SCIENCE - 2

Jim Hower and Leslie Ruppert

15:25 - **Influence of Discard Mineral Matter on Slag-Liquid Formation and Ash Melting Properties of Coal**

- **A Factsage Simulation Study**, JC van Dyk, MJ Keyser, Sasol Technology R&D, SOUTH AFRICA

15:45 - **Coal It's Elementary My Dear Watson**, Jonathan P. Mathews, Vijayaragavan Krishnamoorthy, Enette Louw, Aime H. N. Tchapda, Fidel Castro-Marcano, Vamsi Karri, Dennis A. Alexis, Gareth D. Mitchell, The Pennsylvania State University, USA

16:05 - **Full-Scale Mercury Control Demonstrations: ICR Sampling with Mercury Control**, Jason Laumb, John Kay, Energy & Environmental Research Center, University of North Dakota; Mark Thoma, Otter Tail Power Company, USA

16:25 - **Mercury Speciation and Emission from Pilot-scale PC Furnaces under Air- and Oxy-fired Conditions**, Brydger Van Otten, Andrew Fry, Brad Adams, Reaction Engineering International; Larry Bool, Praxair Inc., USA

16:45 - **The US-China Clean Energy Research Center: Coal Developments**, Jerald J. Fletcher, US-China Energy Center at West Virginia University, USA

17:05 - **The Effect of the Boudouard-reaction on Reaction Rates of Coal Chars in CO₂- and N₂/O₂-Atmospheres at Oxygen Contents from 0% to 30%**, Dominik Christ, Malte Förster, Reinhold Kneer, RWTH Aachen University, GERMANY

ORAL SESSIONS Thursday, September 15, 2011 10:20 - 17:25

SESSION 37 MAJOR CCS DEMONSTRATION PROJECTS: GENERAL - 4

J. Hoffman and C. Miller

10:20 - **Status of the FutureGen 2.0 Oxy-Combustion Large Scale Test Project**, Mark H. Williford, David W. Burbridge, Ameren Energy Resources, USA

10:45 - **FutureGen 2.0 Oxy-Combustion Repowering at Meredosia**, Steve Moorman, Babcock & Wilcox, USA

11:10 - **Air Liquide's Global Roadmap Toward the Industrialization of Oxy-Combustion**, Roger Gilchrist, Mark Estopinal, Etienne Sturm, Jerry Oliver, Air Liquide Engineering & Construction, USA

11:35 - **FutureGen 2.0 CO₂ Transportation & Geologic Sequestration**, Steve Winberg, CONSOL Energy Inc., USA

SESSION 38 GASIFICATION: FUNDAMENTALS

Jenny Tennant and Pete Rozell

10:20 - **Mineralogical Analysis of Coal Chars Obtained by High Temperature Gasification of Gravity and Size Separated Fractions of a High Volatile Bituminous Coal**, Nari Soundarrajan, LaTosha M. Gibson, Nandakumar Krishnamurthy, Sarma V. Pisupati, Pennsylvania State University; Lawrence J. Shadle, DOE/NETL, USA

10:40 - **Particle Deposition Predictions by Critical Viscosity and Mechanistic Particle Deposition Models**, John M. Kuhlman, Weiguo Ai, West Virginia University, USA

11:00 - **Coal Ash Behavior in Reducing Environments (CABRE) III**, Joshua J. Stanislawski, Donald P. McCollor, Kevin C. Galbreath, Daniel H. Schwitala, University of North Dakota, USA

(二) Plenary Session 相關圖片



圖 III.1-1

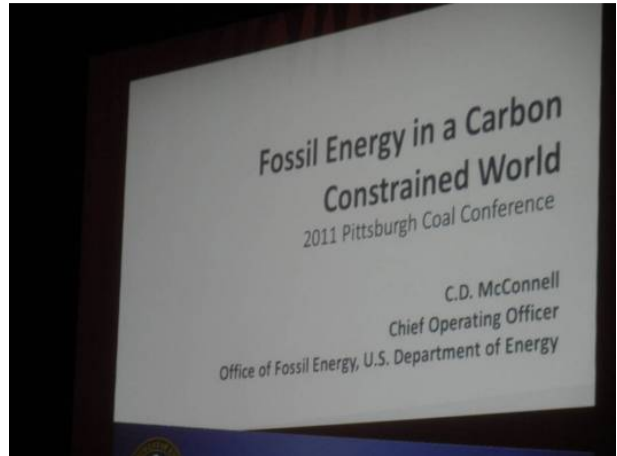


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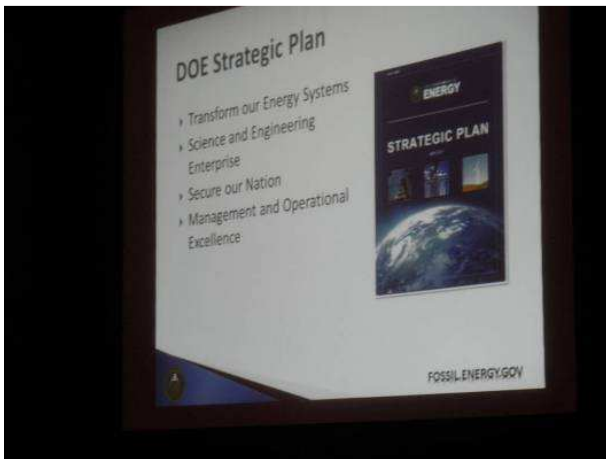


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圖 III.1-4



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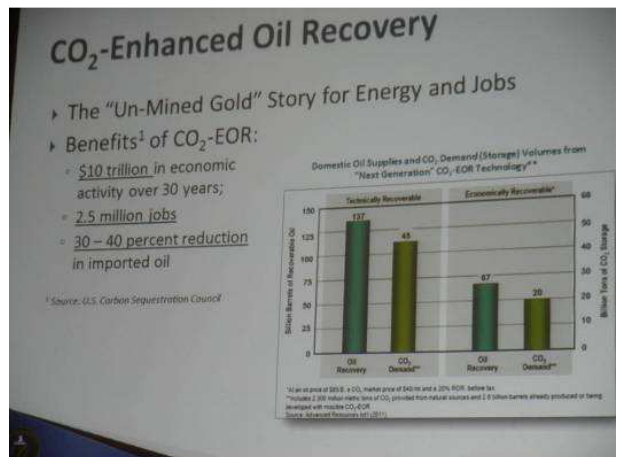


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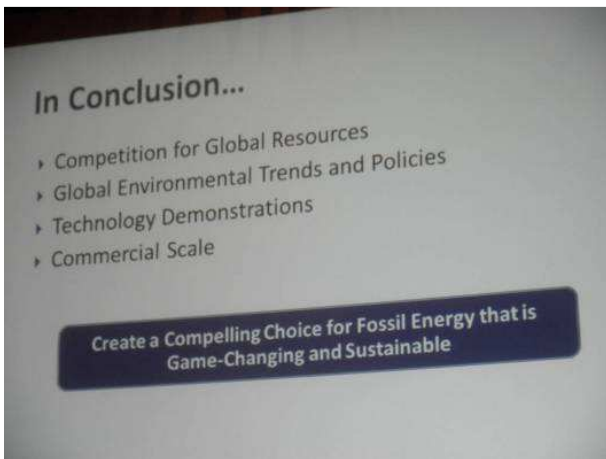


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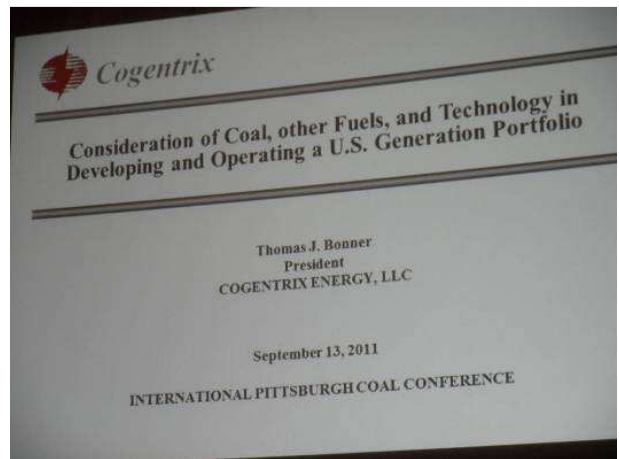


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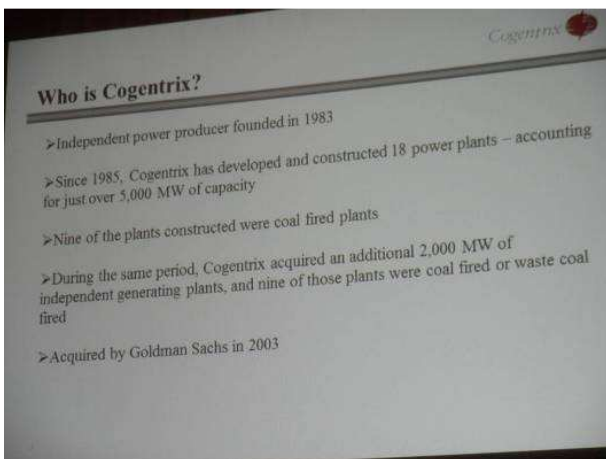


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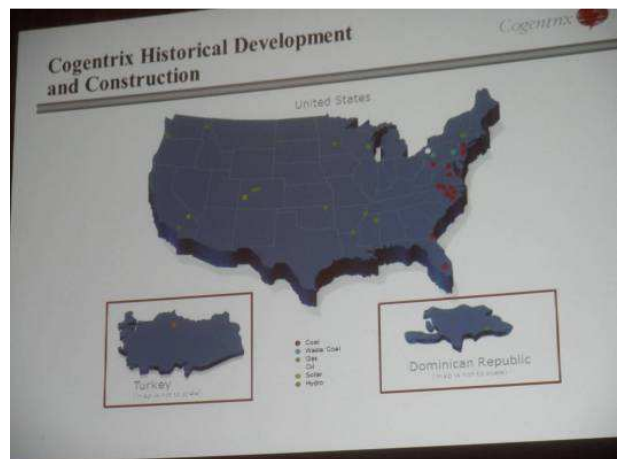


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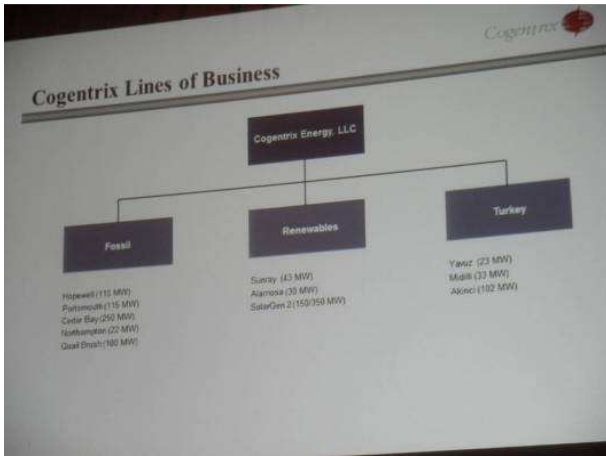


圖 III.1-13



圖 III.1-14

The Cogentrix Project Finance Structure and the Challenges We Face

- > Customer objectives
- > Reserve margins and operating environment
- > Regulation
- > Availability of financing

圖 III.1-15

Customer Objectives

- > Investor owned utilities, municipals and coops – build v. buy
- > Regulatory restrictions
 - > Long term v. short term
 - > Return objectives
- > Accounting and reporting
 - > GAAP issues
 - > Sarbanes Oxley

圖 III.1-16

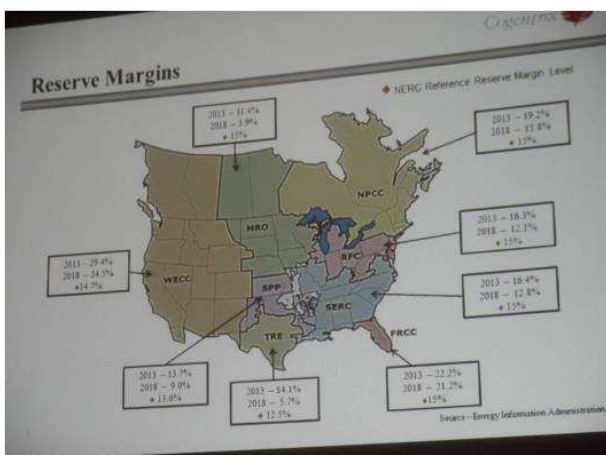


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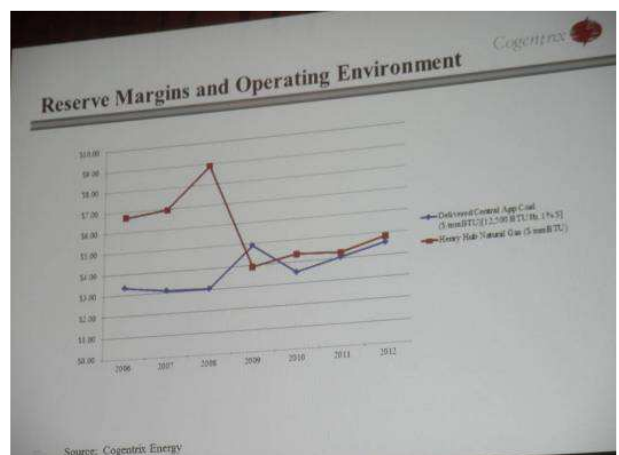


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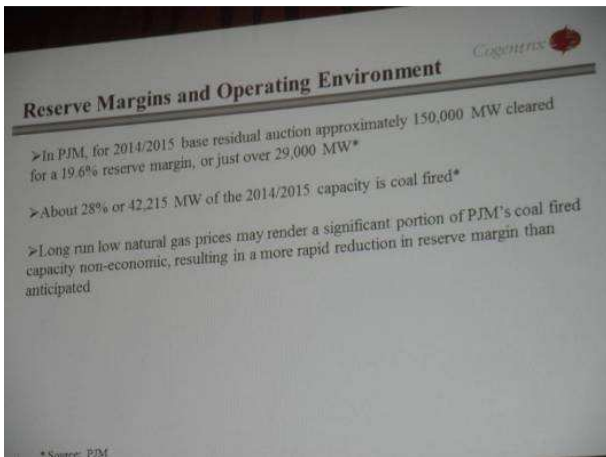


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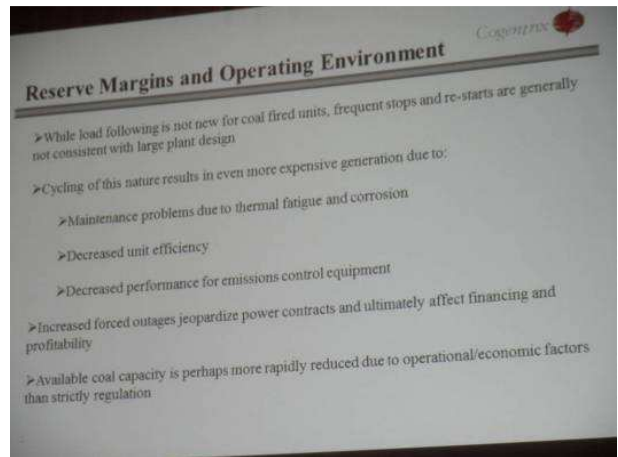


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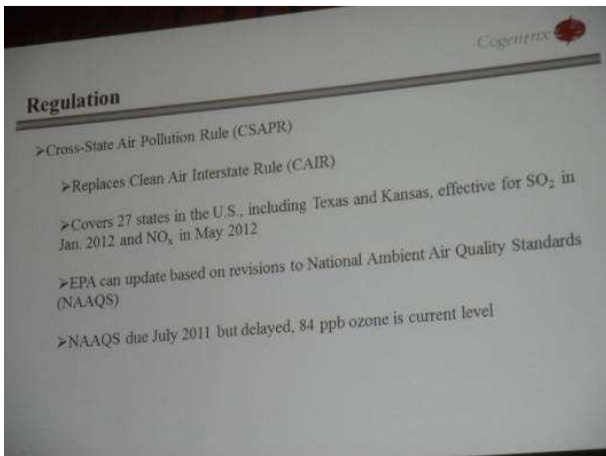


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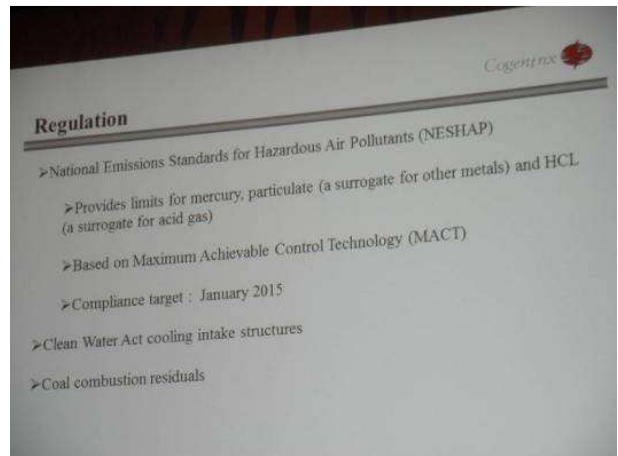


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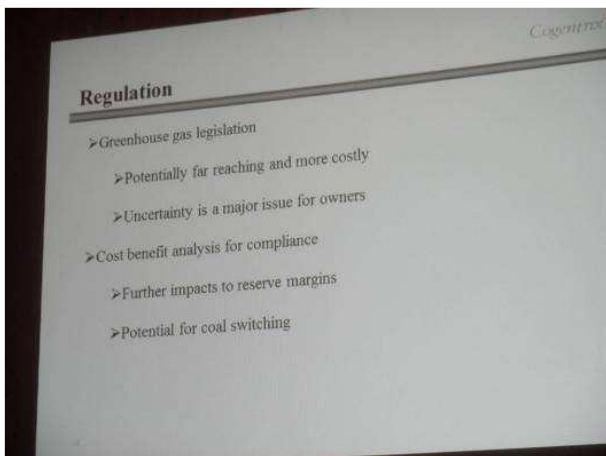


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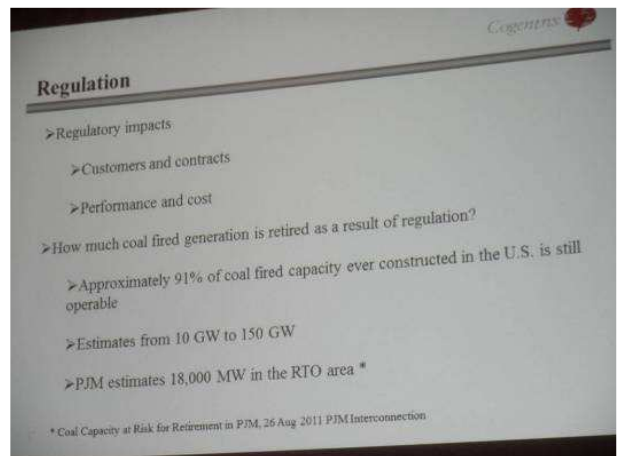


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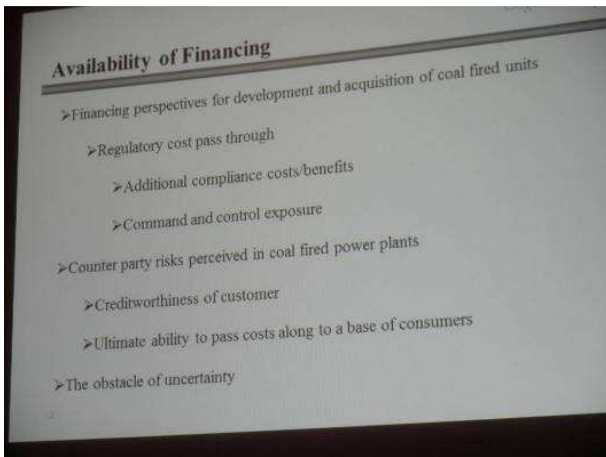


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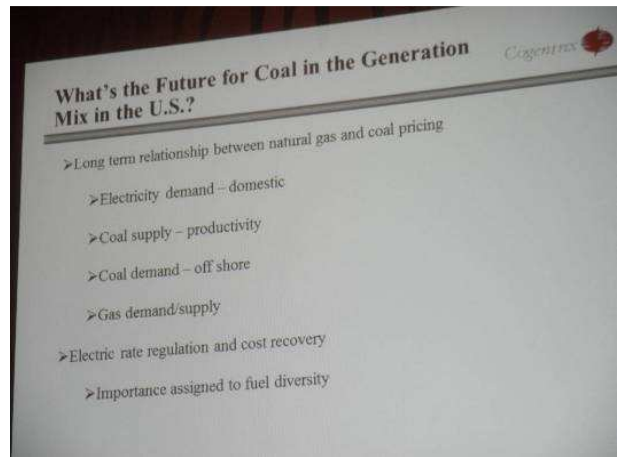


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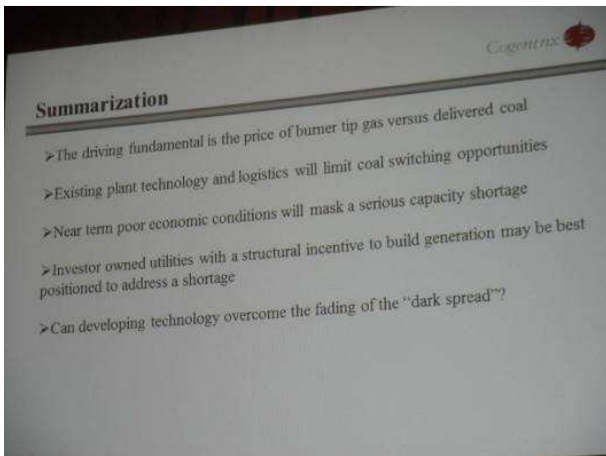


圖 III.1-27



圖 III.1-28



圖 III.1-29

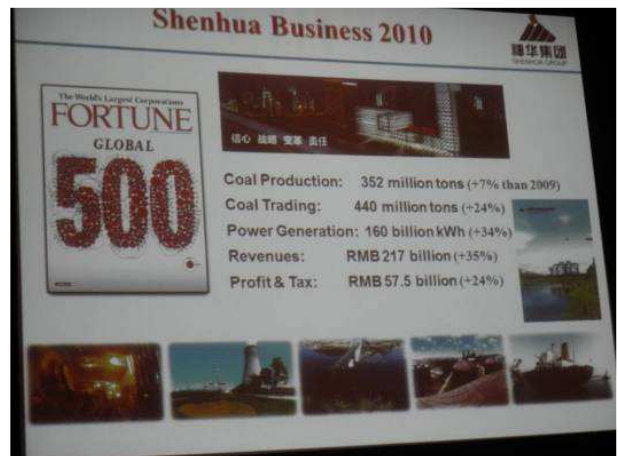


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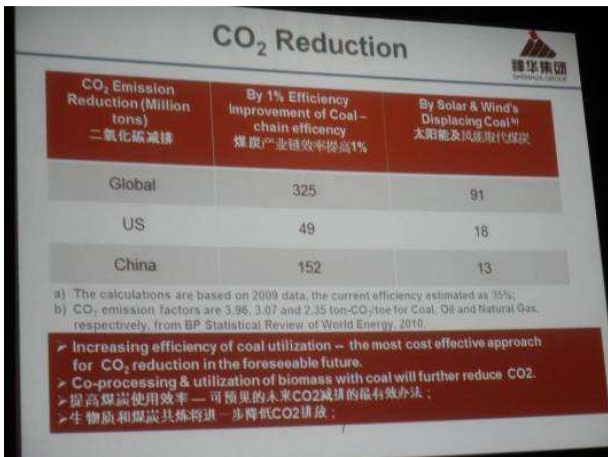


圖 III.1-31



圖 III.1-32



圖 III.1-33

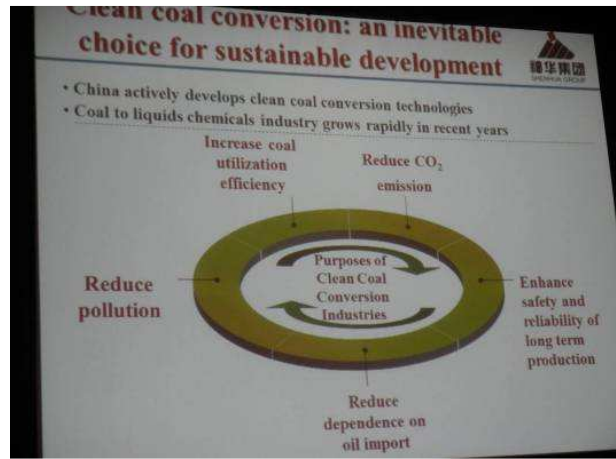


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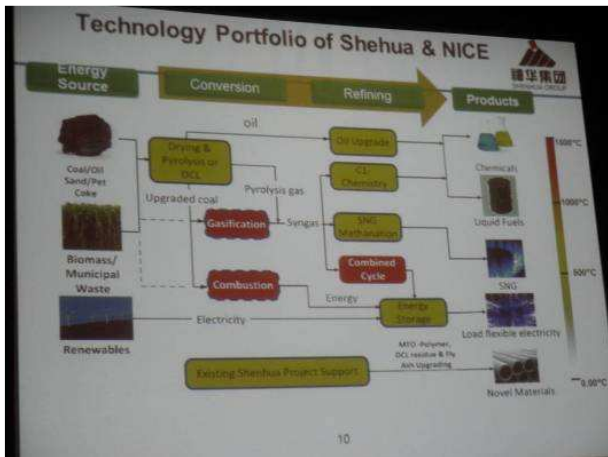


圖 III.1-35



圖 III.1-36

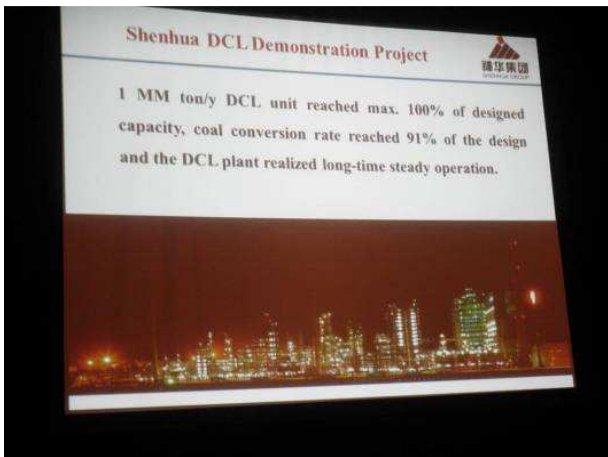


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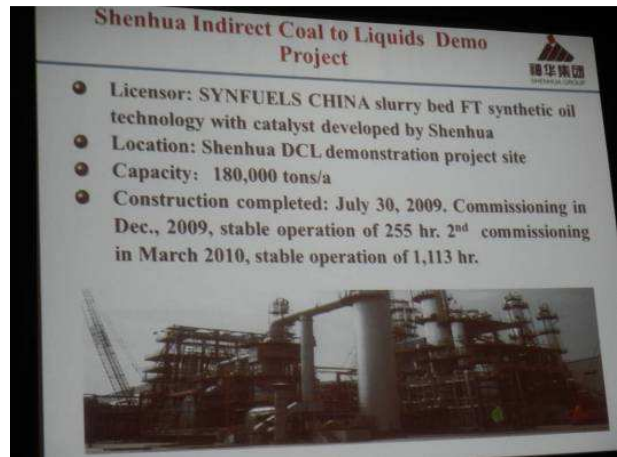


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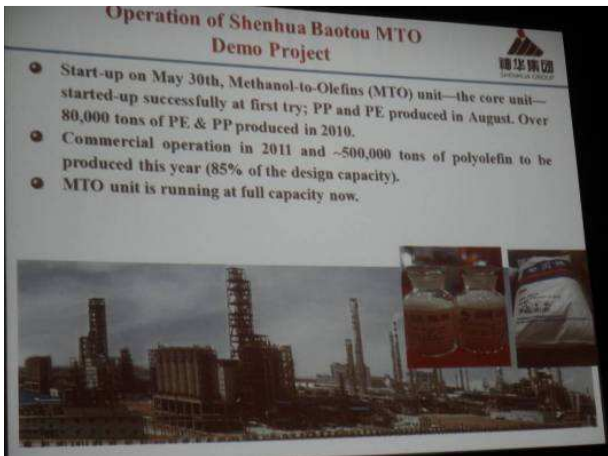


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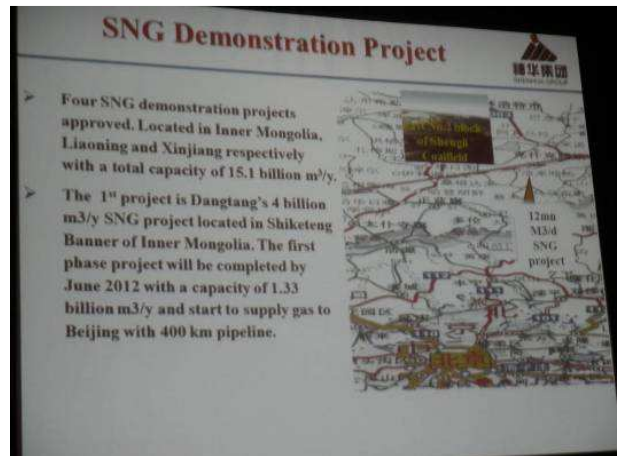


圖 III.1-40



圖 III.1-41

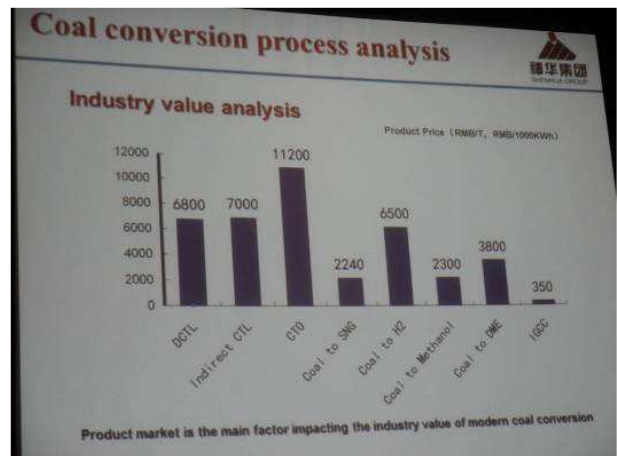


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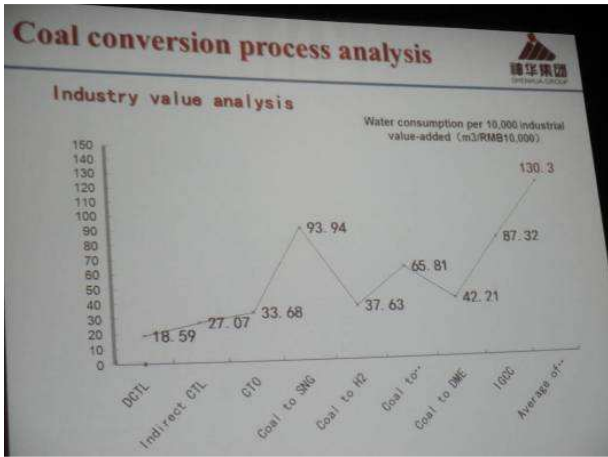


圖 III.1-43

Coal conversion process analysis

Industry value analysis

- In current market price, the value of CTL (either direct or indirect) and CTO are promising
- The current price of NG and H₂ is only 30% of the oil product with the same BTU and 20% of the olefin products with the same BTU.
- According to oil/gas ratio in the current international market, if the price of natural gas or H₂ can be 60% of oil with same BTU, the energy consumption, water consumption and pollutants emission per 10,000 industrial value-added for coal to SNG and H₂ will be close to those in CTO.
- For those areas with no NG, but a lot of Coal, Coal to SNG and H₂ with CO₂ capture could provide the cleaner energy for the local market.

圖 III.1-44

Shenhua Clean Coal Conversion Blueprint during the 12th Five-Year Plan Period

Capacity by the end of the 12th Five-Year Plan period:

- CTL: 10MMTA
- Coal-to-Methanol: 10.85MMTA (including methanol from MTO plant)
- Coal-to-Olefins: 3.8MMTA
- SNG: 1.7 bn m³/y

Total investment: over 100 billion RMB (excluding capital contribution from partners)

圖 III.1-45

Concluding Remarks

- The oil substitution efficiency for CTO and direct CTL is approximately 2.45tce/toe, relatively high and it has potential room to improve.
- If the natural gas price is 60% of oil with the same BTU, the economic and environmental advantages of coal to SNG will appear. In addition, coal to natural gas, with 65% energy conversion efficiency, is an efficient process. The oil substitution factor with coal can be 2.15tce/toe, which is quite promising and is of significant potential.

圖 III.1-46

(三) Technical Paper Session 相關圖片

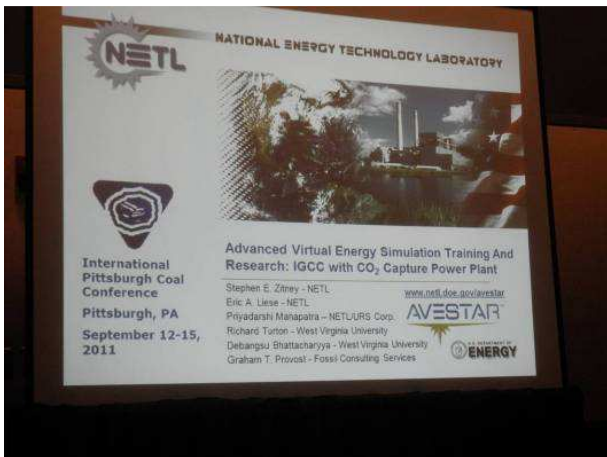


圖 III.2-1

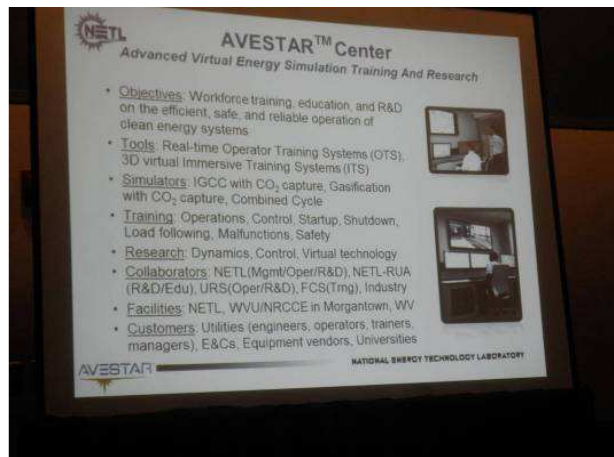


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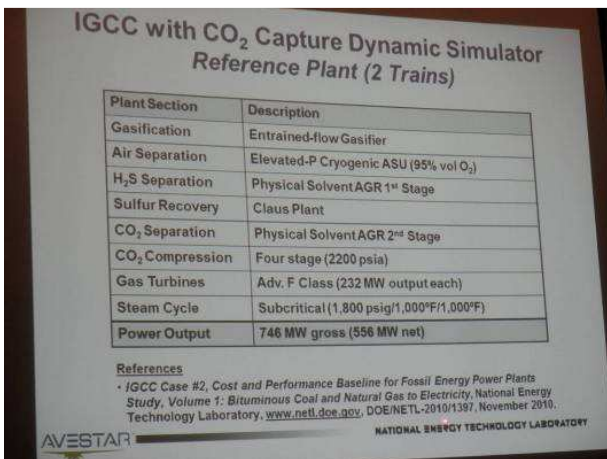


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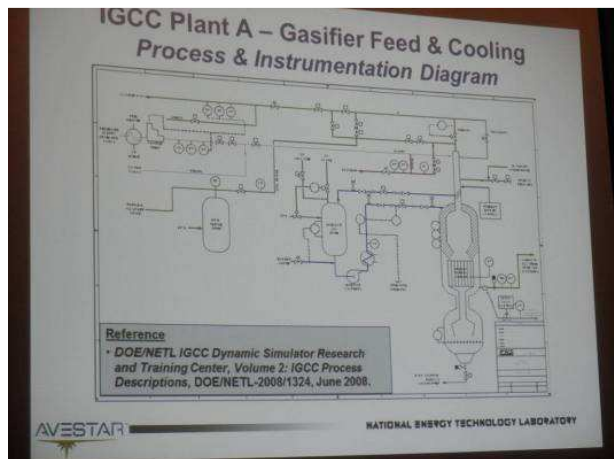


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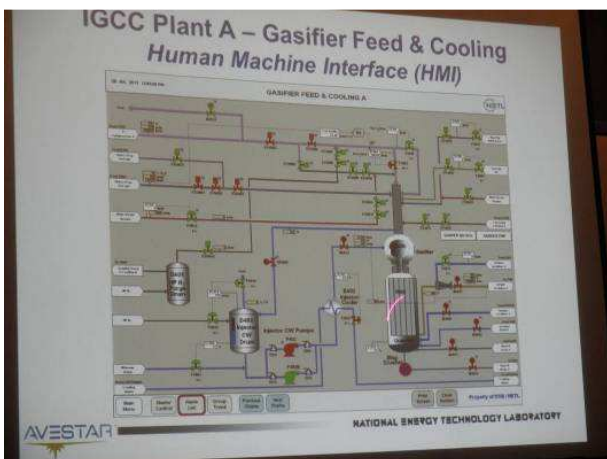


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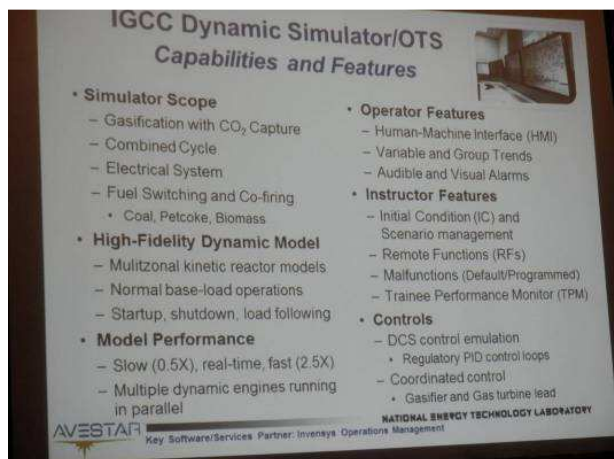


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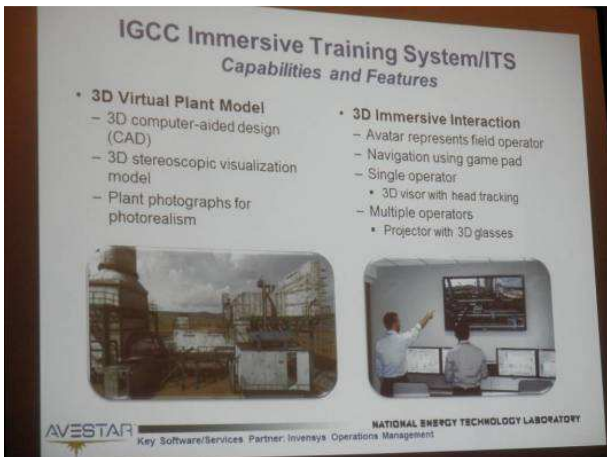


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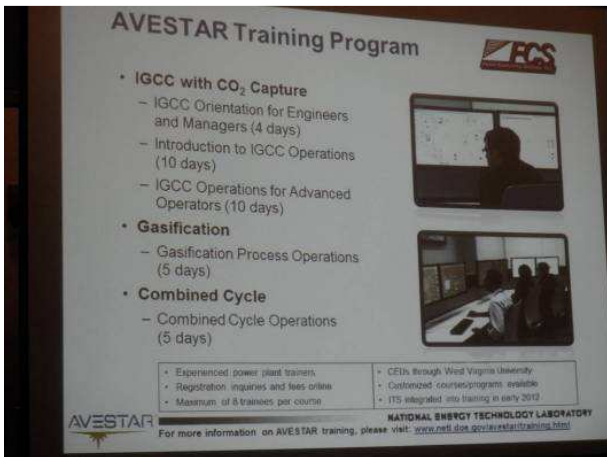


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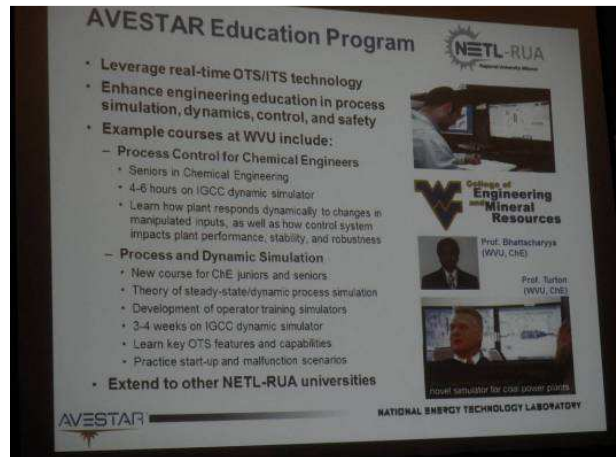


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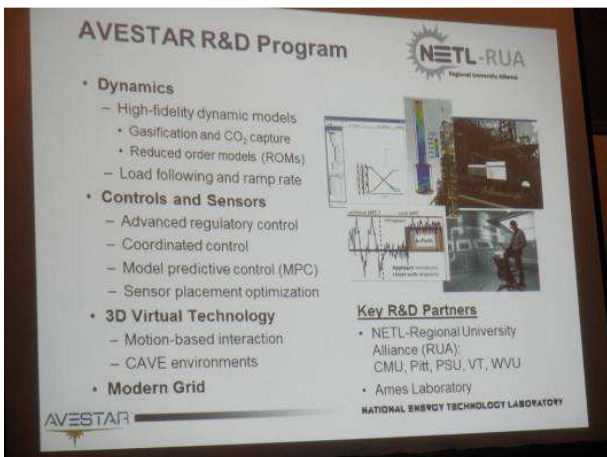


圖 III.2-11



圖 III.2-12

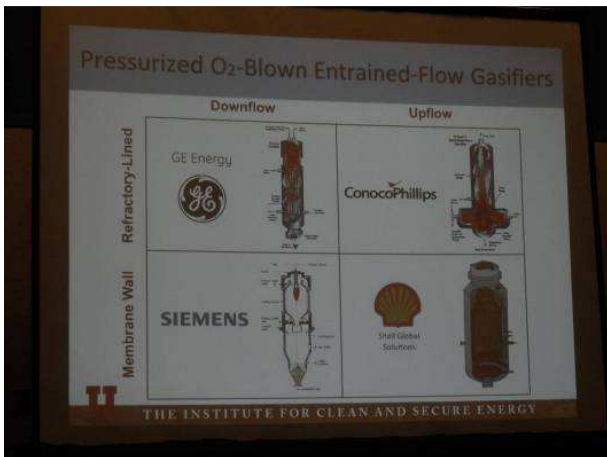


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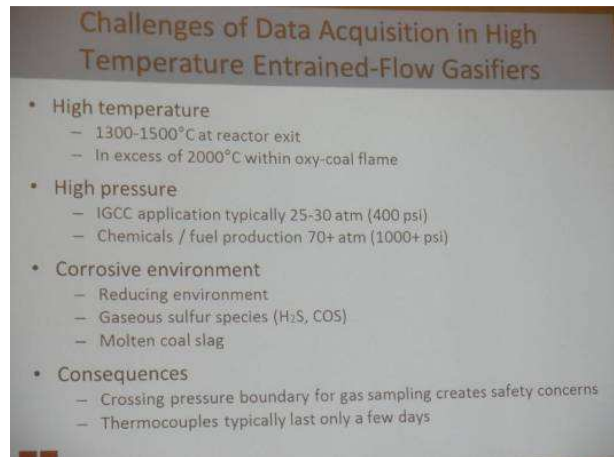


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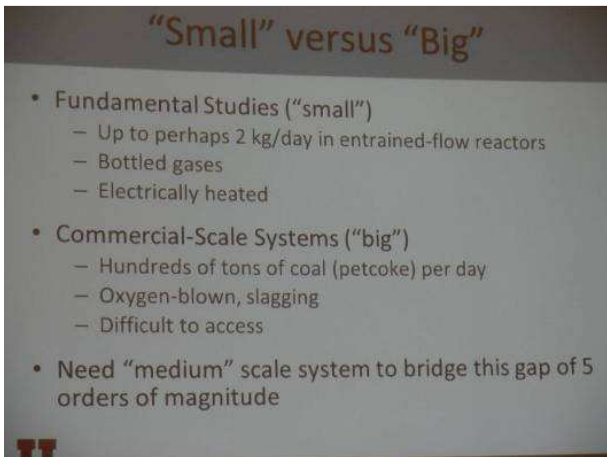


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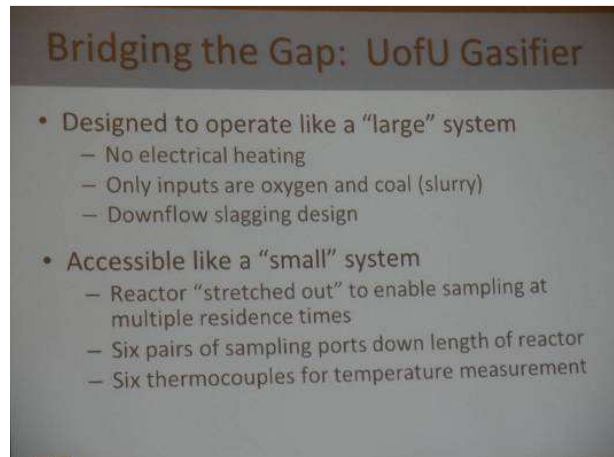


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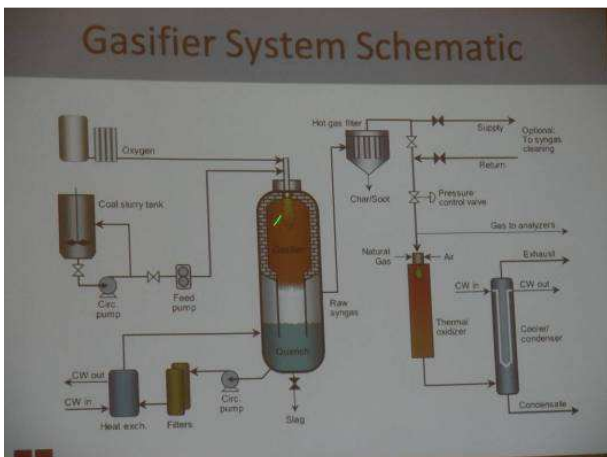


圖 III.2-17

Parameter	Typical (and Maximum) Values	
	AE Units	SI Units
Pressure	250 (450) psi	17 (31) bar
Temperature	2600 (3100) °F	1425 (1700) °C
Slurry feed rate	120 (290) lb/hr	50 (135) kg/h
Dry coal feed rate	70 (170) lb/hr	30 (80) kg/h
Thermal input	0.7 (2.0) MMBtu/hr	220 (600) kW
Slurry concentration	59 (65) wt%	59 (65) wt%
Oxygen feed rate	75 (330) lb/hr	35 (150) kg/h
Syngas production (dry)	2000 (5000) scfh	55 (140) Nm ³ /h

圖 III.2-18

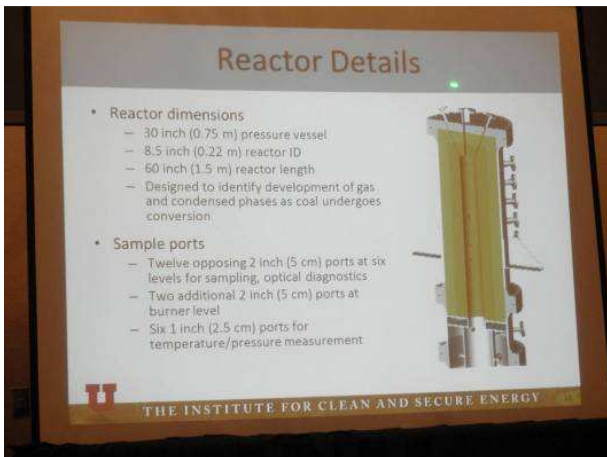


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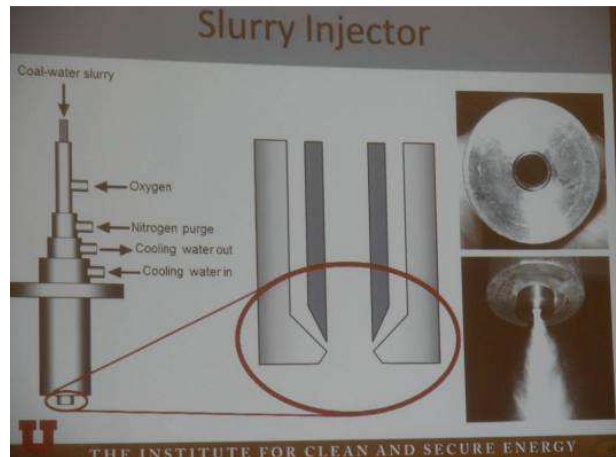


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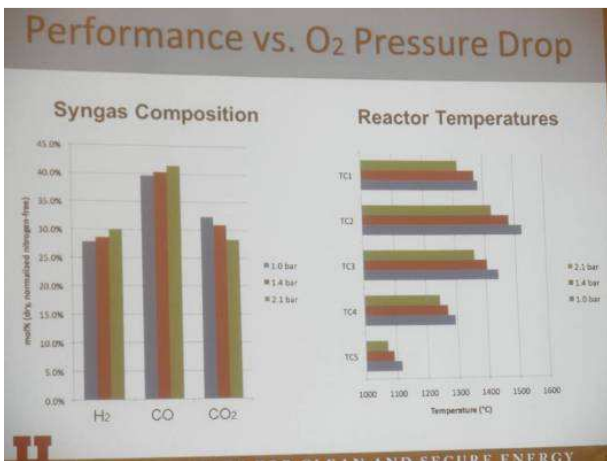


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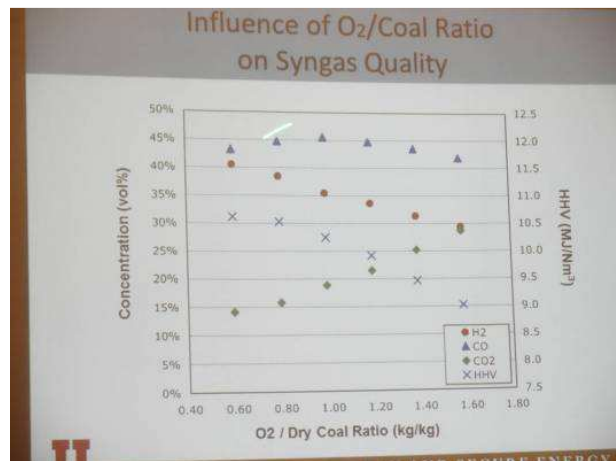


圖 III.2-22

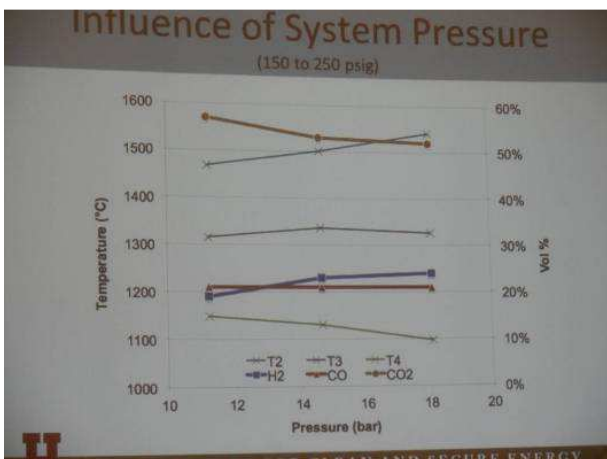


圖 III.2-23

Conclusions

- Semi-pilot scale system (ca. 1.5 ton/day, 500 kW_{th}) offers opportunity for access and analysis of gasifier performance while operating under industrially-relevant conditions
- Gasifier performance strongly tied to injector design and efficiency of fuel distribution
- Trends in performance with varying conditions match expectations
 - O₂/coal ratio
 - System throughput
 - System pressure

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圖 III.2-24

Background

- CSIRO research into gasification fundamentals and their applications
 - Largely focussed on Australian bituminous coals
- Joint program of work between CSIRO and GE Global Research
- Experimental Aspects
 - Coal gasification behaviour
 - High temperature char-steam reaction rate
- Modelling Aspects
 - Confirming some detailed aspects of chemical species formation in submodels of gasification




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圖 III.2-25

Work Program

- Two US coals
- Gasification measurements in a pressurised entrained flow reactor
 - Gasification behaviour under dilute conditions (but with appropriate O:C ratios)
 - Isolating the char-H₂O reaction
- Modelling verification
 - Focussing on the char-steam reaction component

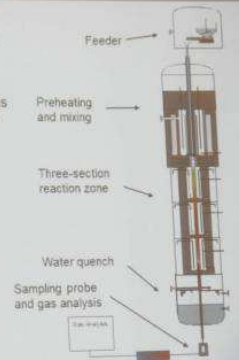



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圖 III.2-26

High Pressure Entrained Flow Reactor (PEFR)

- Entrained-flow reactor
- Capable of 20 bar pressure, 1500°C wall temperature
- Coal feed rate of 1-5 kg/hr
- Gas mixtures of O₂, CO₂, H₂O and N₂
- Adjustable sampling probe - char and gas samples collected at different residence times (0.5-3s)





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圖 III.2-27

1. Gasification Behaviour

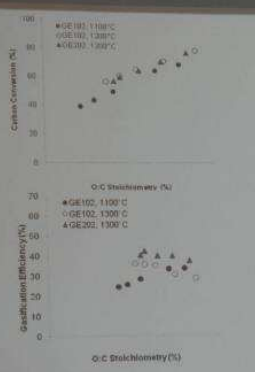
- Measurement of coal conversion behaviour under 'simulated' entrained flow gasification conditions
- Similar approach to that used in previous work using Australian coals
 - D. J. Harris, D. G. Roberts and D. G. Henderson, *Gasification behaviour of Australian coals at high temperature and pressure*, Fuel, **85**(2) 134-142 (2006)
- 20 bar pressure, 2.5% O₂ in N₂
 - Dilute mixture; O:C ratios are relevant
 - Residence times 0.5-3.0 s
 - 1100°C and 1300°C wall temperatures
 - Produces data that are consistent with coal performance at larger scales
 - D. G. Roberts, A. Y. Ilyushechkin, A. Tramel and D. Harris, *4th International Freiberg Conference on IGCC and XII Technologies*, Dresden, Germany (2010).



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圖 III.2-28

Results: Effects of O:C ratios




- Increasing O:C ratio increases conversion (at constant wall temperature)
- Two coals similar
- Increases in wall temperature, as expected, increases conversion
- O:C ratio impacts on conversion (as above) as well as quality of syngas
- Peak around O:C=1.1 in previous published work using Australian coals.

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圖 III.2-29

Results: Impacts of residence time



- Conversion and 'gasification efficiency' strongly linked to residence time
 - Consistent with our understanding
- Relative impacts of volatile release and char gasification clear
- Stoichiometry effects on gas'n efficiency are small under these conditions
 - Competing effects on conversion and gas quality

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圖 III.2-30

2. High Temperature Char-H₂O Reactivity

- Isolate the reaction between char and H₂O
 - Feed coal with a mixture of H₂O/N₂
 - Include sufficient O₂ to combust only volatiles expected to be released
 - Measure conversion from the point at which [O₂] = 0%
- Recent work studying the char-CO₂ reaction provided important insights into rate processes at high temperatures and pressures
- First of a kind measurements

圖 III.2-31

Results: Char-Steam Reaction

Residence time (s)	1450°C Conversion (%)	1300°C Conversion (%)	1150°C Conversion (%)
10	35	30	25
20	45	40	35
30	55	50	45
40	65	60	55
50	75	70	65
60	85	80	75
70	90	85	80

- Clear impact of temperature on char-H₂O reaction rate
- Consistent with previous work studying the high temperature C-CO₂ reaction

圖 III.2-32

3. Testing Kinetics Submodels: Char-Steam Reaction

- Experimental conversion data
 - Determined using concentrations of CO, CO₂, and CH₄
- Two model predictions made
 - Considering only CO, CO₂, CH₄ (solid line)
 - Considering all possible C-species, including hydrocarbons (dashed line)
- Solid line should therefore match the data
- High temperature (1300°C) agreement reasonable, lower temperature less so
- Possible areas for ongoing work on submodel include
 - Role and fate of HCs
 - Complex high T, P char reactivity and structure considerations

圖 III.2-33

Steady-State Modeling of a Single-Stage, Downward-Firing, Entrained-Flow Gasifier

Job S. Kasule^{1,2}, Richard Turton^{1,2}, Debangsu Bhattacharyya^{1,2}, Stephen E. Zitney¹

¹U.S. Department of Energy, National Energy Technology Laboratory, Morgantown, WV 26507

²Department of Chemical Engineering, West Virginia University, Morgantown, WV 26506

International Pittsburgh Coal Conference, September 12-15, 2011

圖 III.2-34

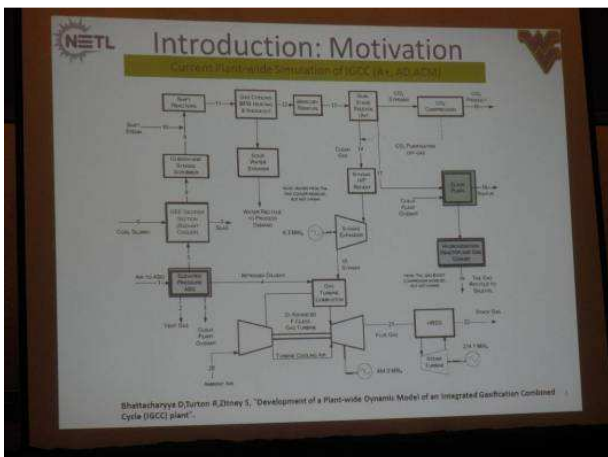


圖 III.2-35

Objectives

- Develop a detailed steady state entrained gasifier Model.
- Extend steady state model to dynamic model

圖 III.2-36

Model: Heterogeneous Rxns

Reaction	Stoichiometry
Char combustion	$C + \frac{1}{\phi} O_2 \rightarrow \left(2 - \frac{2}{\phi}\right) CO + \left(\frac{2}{\phi} - 1\right) CO_2$
Steam gasification	$C + H_2O \leftrightarrow CO + H_2$
CO ₂ gasification	$C + CO_2 \leftrightarrow 2CO$
H ₂ gasification	$C + H_2 \leftrightarrow CH_4$

圖 III.2-37

Model: Homogeneous reactions

$$CO + \frac{1}{2} O_2 \rightarrow CO_2$$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$$

$$CO + H_2O \leftrightarrow CO_2 + H_2$$

$$CH_4 + H_2O \leftrightarrow CO + 3H_2$$

$$\frac{1}{2} N_2 + \frac{3}{2} H_2 \rightarrow NH_3$$

圖 III.2-38

Other model attributes

- A heuristic recirculation model has been incorporated to simulate the energy transfer for the initial stage processes.

圖 III.2-39

Model: Wall energy balance

- Many previous studies have assumed a linear temperature profile.
- No *a priori* wall temperature was assumed.
- Detailed wall energy balance is thus included.

圖 III.2-40

Simplified representation of energy transfer in gasifier

- Radiative transfer between solid-wall, wall-gas, wall-wall,
- Convective transfer
- Conduction away from the wall to surface

圖 III.2-41

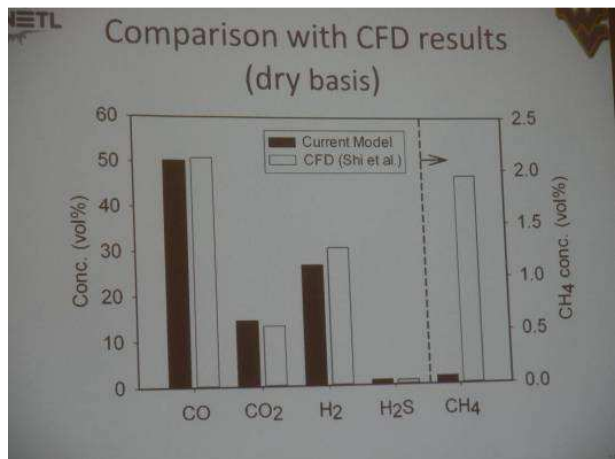


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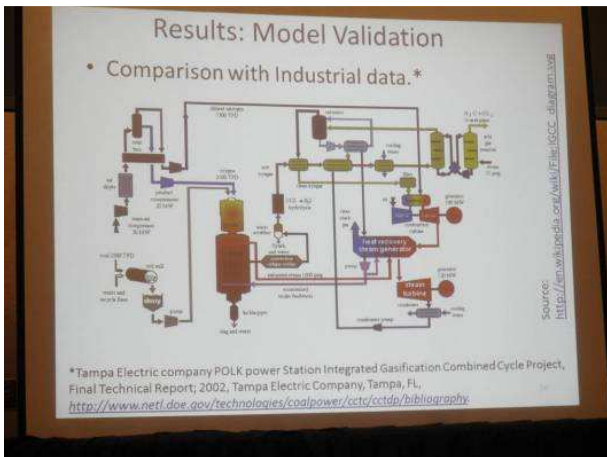


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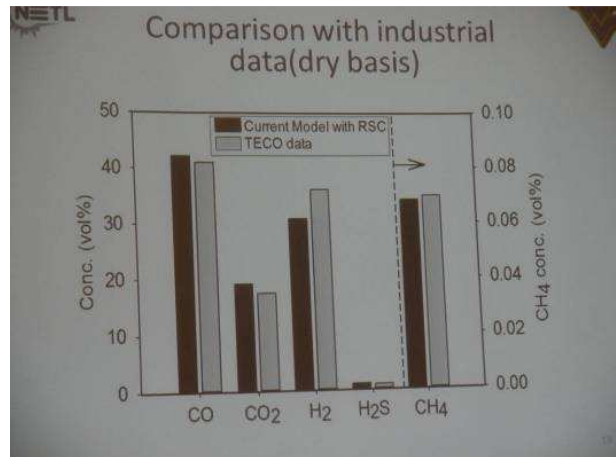


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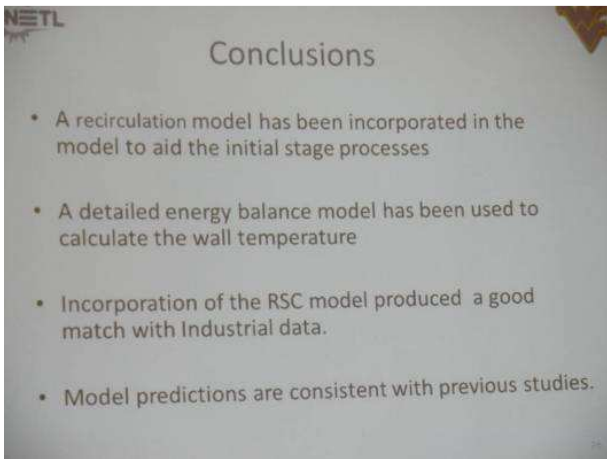


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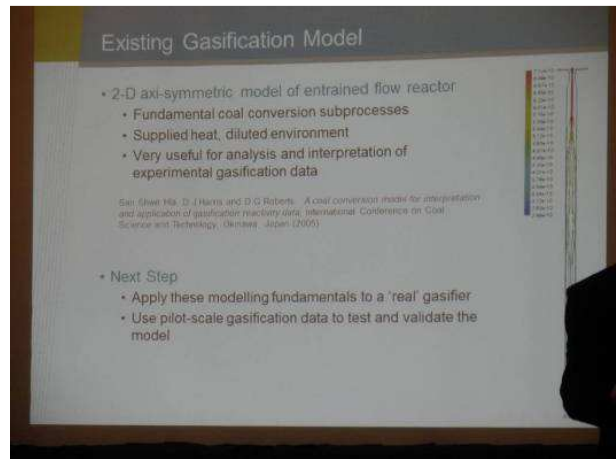


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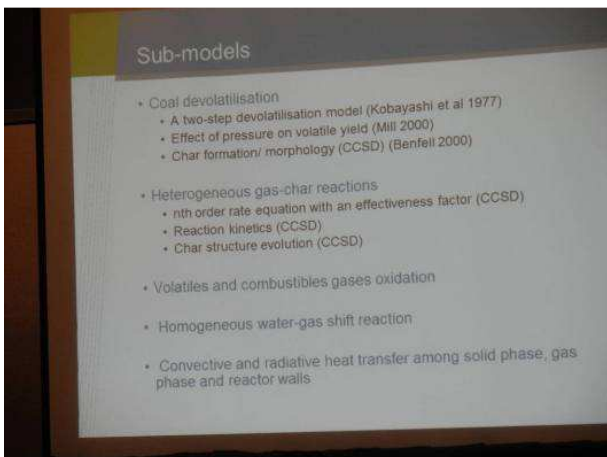


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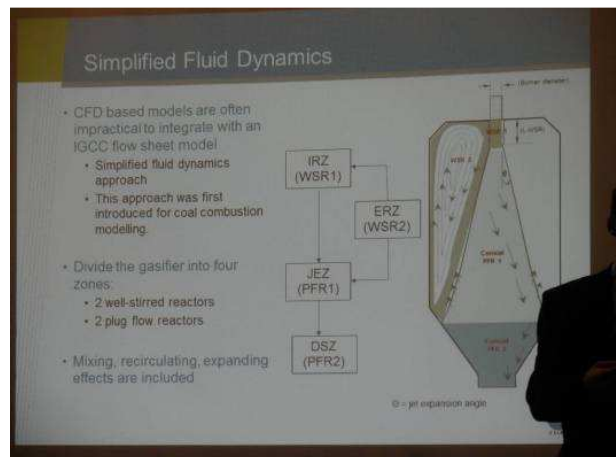


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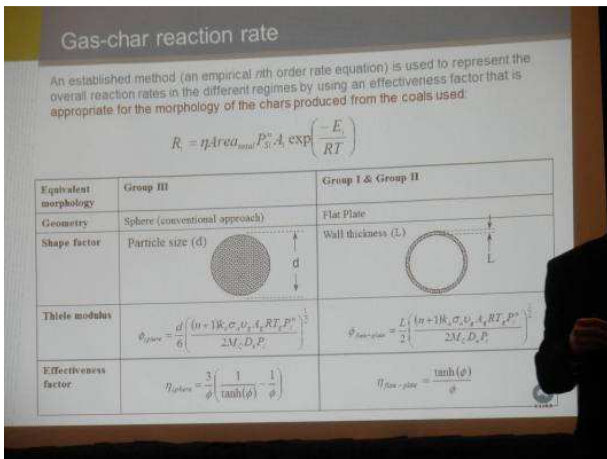


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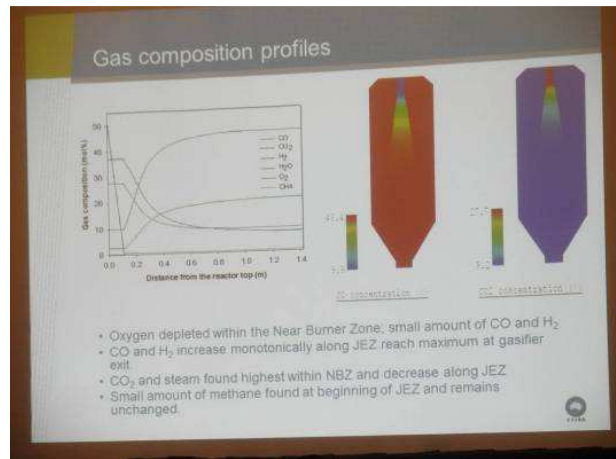


圖 III.2-50

Base-line operating parameter for each coals

Coal	CRC701	CRC702	CRC703	CRC704
Coal flow rate (kg/h)	342.6	285.6	298.4	297.4
Oxygen flow rate (Nm ³ /h)	291.0	299.2	300.3	303.4
Nitrogen flow rate (Nm ³ /h)	116.0	124.0	118.0	129.0
O:C ratio	1.24	1.32	1.20	1.47

圖 III.2-51

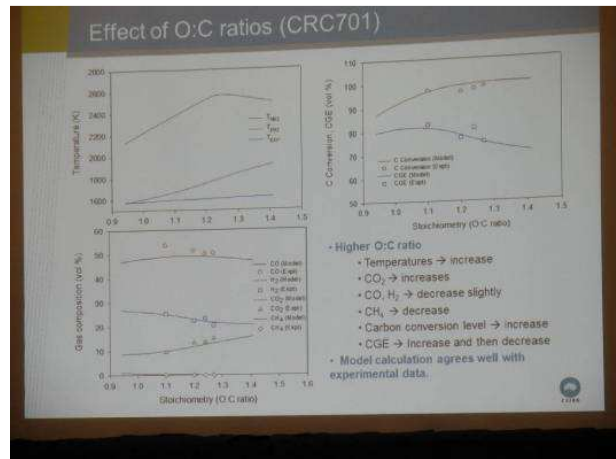


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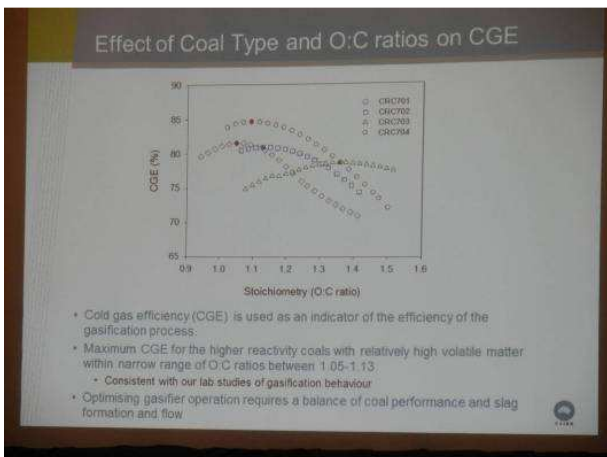


圖 III.2-53

Summary and Conclusions

- This work has incorporated and updated our existing gasification reaction model into a newly-developed gasifier model
- The gasifier model is a practical, simple model consisting of four reaction zones.
 - Ongoing work to integrate this gasifier model with an IGCC flowsheet to assess impacts of coal performance on wider IGCC and IGCC-CCS system performance
- Model is able to reflect the significant differences in gasification behaviour of the four coals, which is consistent with lab-scale and larger-scale investigations using these coals.
 - Ongoing work to incorporate slag formation and flow requirements
- This work continues to demonstrate that bench-scale gasification data can be applied to far more complex high pressure and high temperature conditions using appropriate mechanisms and sub-models.

圖 III.2-54

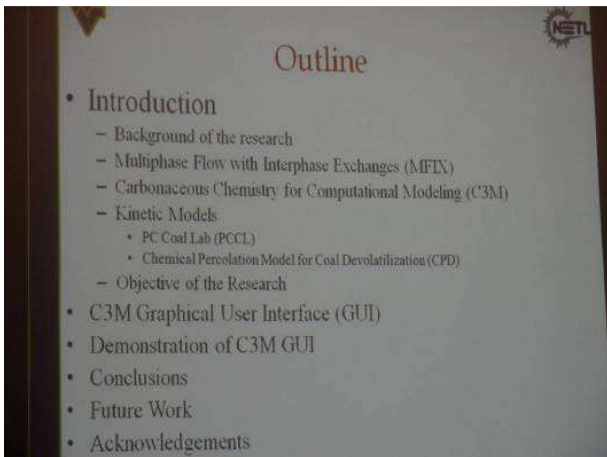


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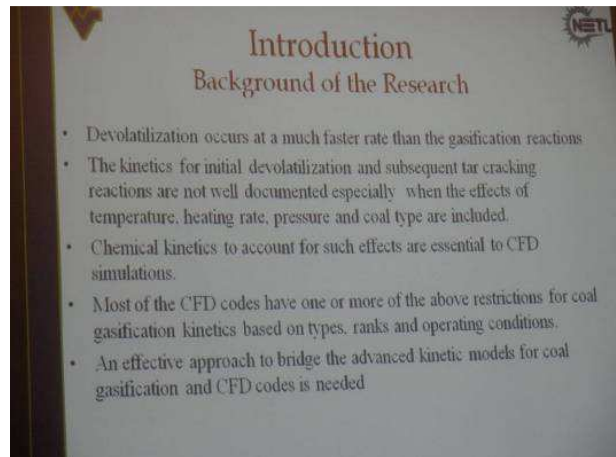


圖 III.2-56



圖 III.2-57

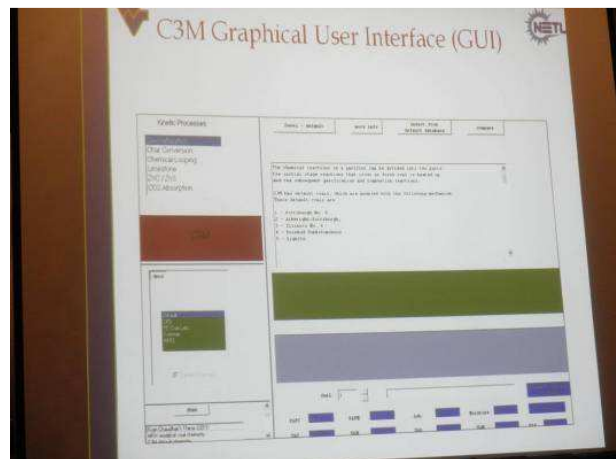


圖 III.2-58

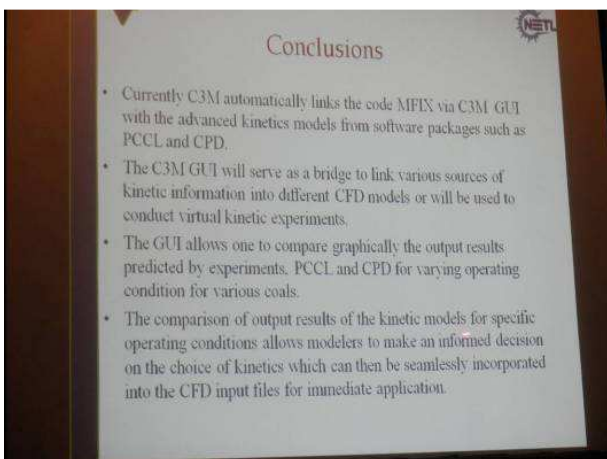


圖 III.2-59

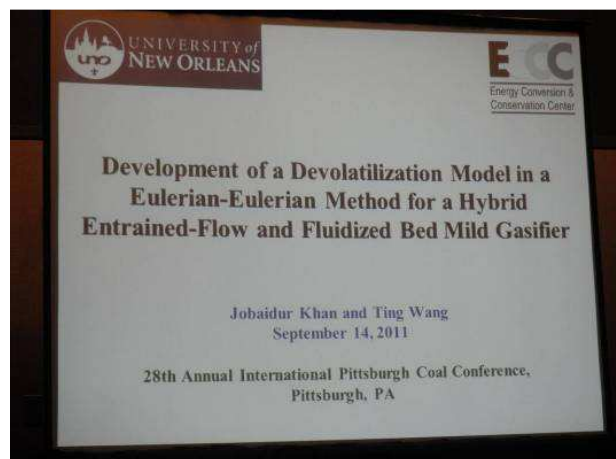


圖 III.2-60



圖 III.2-61

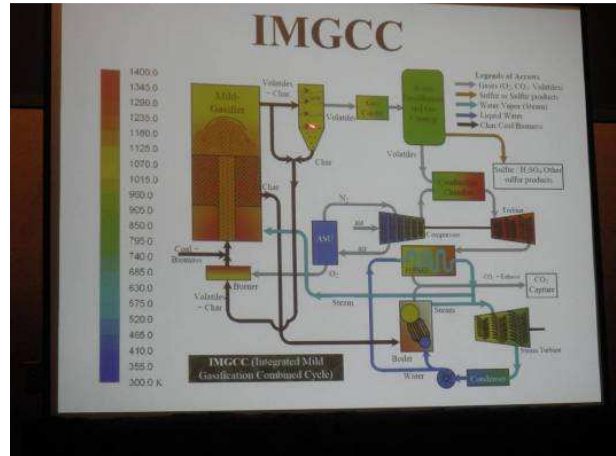


圖 III.2-62

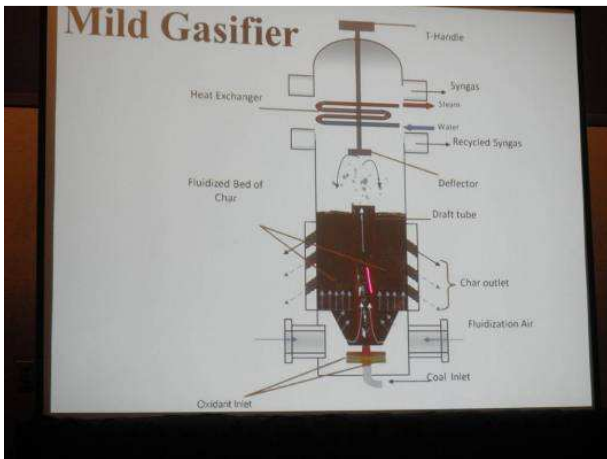


圖 III.2-63

- ### Motivations
1. Volatiles are high energy-density fuel and can be burned in the combustion chamber, so energy can be saved by not burning them in the gasifier.
 2. Retrofit an existing coal-fired power plant in order to use existing facilities (eg. boiler) and achieve lower emissions and significantly improved thermal efficiency.
 3. Design a Mild-Gasifier by studying different parameters.
 4. No devolatilization model is facilitated in Eulerian-Eulerian method in ANSYS/FLUENT.

圖 III.2-64

Global Gasification Reactions

Reaction	Reaction Type	Heat Transfer (kJ/mol)	Parameters for $\ln = A(T)^n \exp(-E/RT)$
			A (s ⁻¹) n E (kJ/mol) m
Heterogeneous			
1. $C(s) + \frac{1}{2}O_2 = CO$	Partial Combustion	$\Delta H_p^\circ = -110.5$	0.002 0.7 x 10 ¹⁰ 0
2. $C(s) + CO_2 = 2CO$	Gasification, Boudouard reaction	$\Delta H_p^\circ = +172.0$	0.0752 1.120 x 10 ¹⁰ 0
3. $C(s) + H_2O = CO + H_2$	Gasification	$\Delta H_p^\circ = +131.4$	0.0702 1.15 x 10 ¹⁰ 0
4. $CO(s) + 2H_2 = CH_4$	Direct Methanation	$\Delta H_p^\circ = -47.4$	
Homogeneous			
5. $CO + \frac{1}{2}O_2 = CO_2$	Combustion	$\Delta H_p^\circ = -283.1$	2.3 x 10 ¹² 1.67 x 10 ¹⁰ 0
6. $CO + H_2O = CO_2 + H_2$	Water-gas	$\Delta H_p^\circ = -41.0$	2.75 x 10 ¹¹ 8.38 x 10 ¹⁰ 0
7. $CH_4 + O_2 \text{ (var)} = 0.5855CO + 0.8522H_2 + 0.06907C_2H_6$	Volatiles Cracking		1.0 x 10 ¹¹ 1.0 x 10 ¹⁰ 0
8. $C_6H_6 + 3O_2 = 6CO + 3H_2$	Gasification		1.0 x 10 ¹¹ 1.0 x 10 ¹⁰ 0
9. $CO + 3H_2 = CH_4 + H_2O$	Methanation	$\Delta H_p^\circ = -205.7$	

* All ΔH_p° at 25°C and 1 atm.
 + = Endothermic (absorbing heat) - = Exothermic (releasing heat)

圖 III.2-65

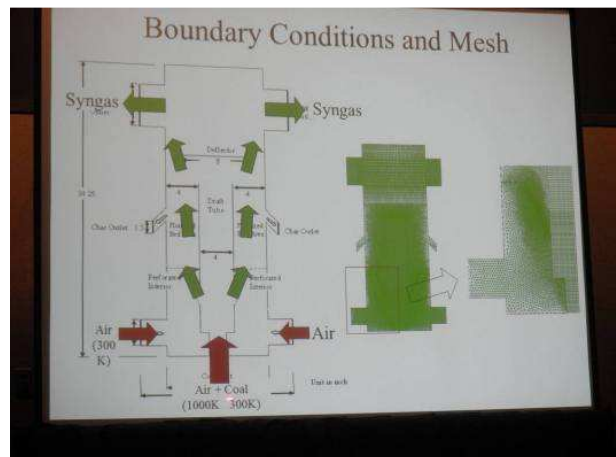


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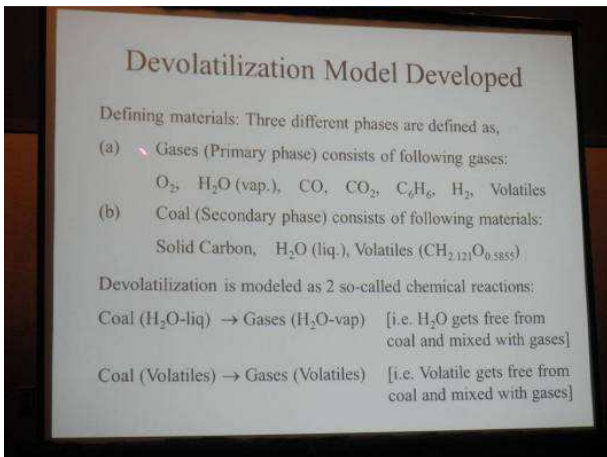


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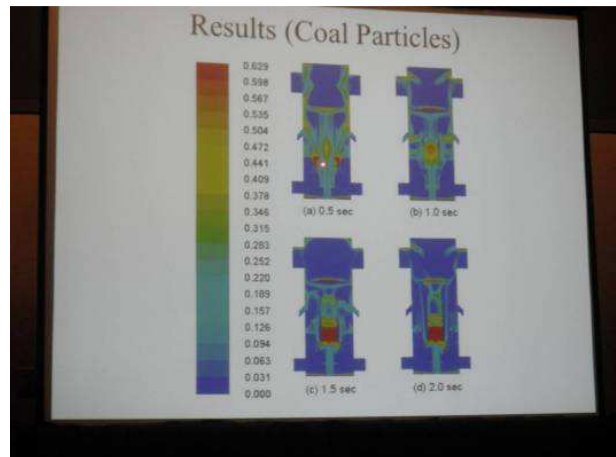


圖 III.2-68

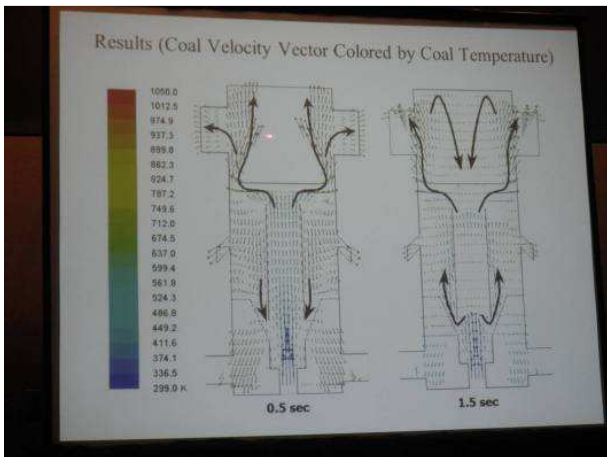


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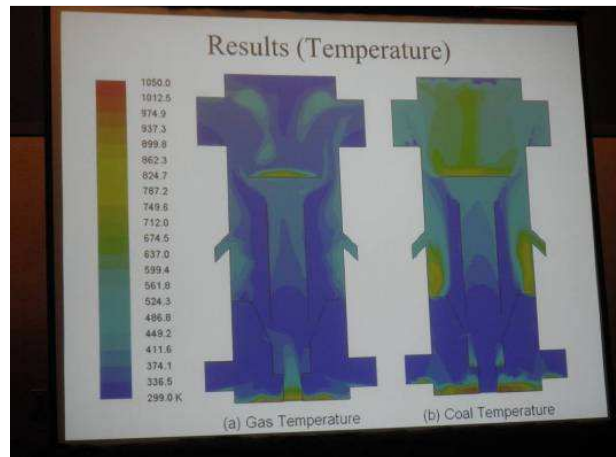


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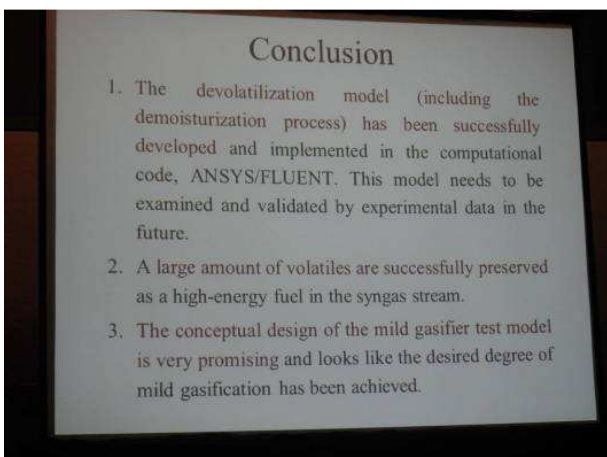


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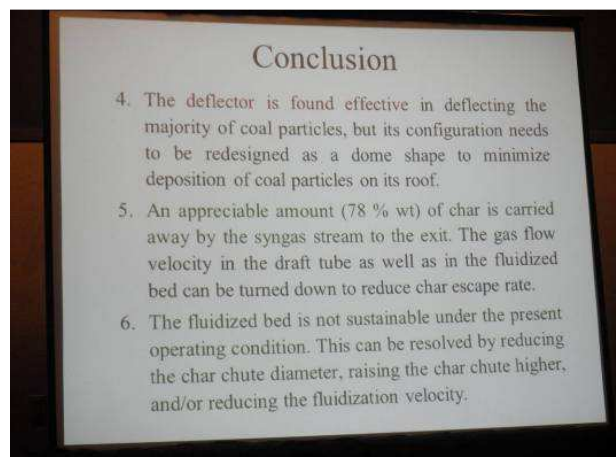


圖 III.2-72

(四) 發表之論文投影片

2011 International Pittsburgh Coal Conference
Pittsburgh, PA, USA, September 12 – 15, 2011

Numerical Analysis of Gasification Performance via Finite-Rate Model in a Cross-Type Two-Stage Gasifier

Yan-Tsan Luan, Yau-Pin Chyau
Institute of Nuclear Energy Research (INER), Longtan, TAIWAN

Ting Wang
University of New Orleans, New Orleans, Louisiana, USA
INER Institute of Nuclear Energy Research

圖 III.3-1

CONTENTS

- Background
- Model Description
- Methodology
- Results and Discussion
- Summary

INER (Institute of Nuclear Energy Research)

- History: founded since 1968 and currently under the administration of Atomic Energy Council (AEC).
- Mission: the sole national research institute, dedicated to energy technologies R&D and promotion for peaceful applications of nuclear science in Taiwan.
- Location: in Longtan, Taoyuan County, ~30 miles SW away from Taipei (about 1 hour drive), in scenic and historic suburban surroundings close to the Shimen Reservoir.

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圖 III.3-2

Background
World Energy Demand & Electricity

- In the IEO2010 Reference case, world marketed energy consumption grows by 49% from 2007 to 2035.
- Fossil fuels are continued supplying much of the energy used worldwide. The Coal shares of world marketed energy consumption raises from 26.7% in 2007 to 27.9% in 2035.
- World net electricity generation increases by 87% in the Reference case, from 18.8 trillion kWh in 2007 to 35.2 trillion kWh in 2035. Coal-fired generation which shares 43% of world net electricity in 2035 increases by an annual average of 2.3% in the Reference case.

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圖 III.3-3

Background
Taiwan's condition & Energy policy

- **Primary Energy Demand in 2009**
 - 42.79% Crude Oil & Petroleum Products
 - 33.08% Coal & Coal Products
 - 14.1% Natural Gas
 - 9.54% Nuclear Power
 - 0.08% Solar Photovoltaic and Wind Power
 - 0.32% Conventional Hydro Power
 - 0.1% Solar Thermal
- **Past amount and predicted future amount of CO₂ emission**
 - If the amount of injected CO₂ is over 90 Mt. by 2025, the amount of CO₂ emission in 2025 will be identical with that in 2000. (governmental goal)
- **Energy policy:**
 1. Raise energy efficiency
 2. Develop clean energy
 3. Ensure steady energy supplement

Clean coal technology → Coal gasification + CCS

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圖 III.3-4

Background
Previous work on gasification modeling in INER

- **2009-2010:**
 - During the development of gasification model of INER, an intermediate step was undertaken by applying "instantaneous gasification model" to the heterogeneous reactions by assuming that the carbon solid is instantaneously gasified, and the reaction rate of each reaction is determined by the turbulence eddies via the eddy-dissipation model.
 - The overall results revealed that the instantaneous gasification model can quickly obtain preliminary results of coal combustion and gasification in a two-stage entrained-flow gasifier.

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圖 III.3-5

Motivation

- In the next decade, coal-fired power generation will continue to be the main power source in Taiwan, therefore, it is essential to develop new technologies such as coal gasification that can extend the usability of coal more cleanly and efficiently.
- The main objective of this paper is to replace the previous instantaneous gasification model with the more realistic heterogeneous finite-rate model to improve the understanding of the gasification processes in the E-Gas like gasifier as well as to investigate the effects of operating parameters.
- The ultimate goal is to use the developed CFD modeling capability and the knowledge gained during parametric gasification analyses to design and establish a demonstration facility in INER.

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圖 III.3-6

Model Description

The Wabash River IGCC Power Plant

- In July 1992 the Destec gasifier was used as demonstration of repowering a pulverized coal-fired boiler using an integrated gasification combined-cycle (IGCC) system.
- Commercial operation began in November 1995.

Plant Performance			
	Design	Actual	Actual
	Coal	Coal	Petecke
Throughput, tons/day	2,550	2,450	2,800
Slurry Output, 10 ³ lbs/hr	1,750	1,650	1,650
Gas Turbine, MWe	192	192	192
Steam Turbine, MWe	185	90*	90*
Parabolic Load, MWe	35	36	36
Net Power, MWe	262	252	252
Plant Efficiency (HRV), %	37.8*	39.7*	40.2*
Sulfur Removal, %	>98	>99	>99

*Lower steam turbine output resulted from freshwater heater failure. Thermal efficiency numbers are corrected for this failure.

Source: DOE, 2000. The Wabash River Coal Gasification Repowering Project

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圖 III.3-7

Model Description

E-Gas (Destec) type Gasifier

- Two stages: a slagging first stage and an entrained-flow, non-slugging second stage.**
- Cross-type gasifier, slurry feed, oxygen blown.**
- In the first stage:**
 - The fuel slurry is partially combusted with oxygen at nominal conditions of 2,600 F and 400 psia.
 - Oxygen and slurry are fed into the first stage through two opposed mixing nozzles of proprietary design.
- In the second stage:**
 - Only additional slurry is injected.
 - The endothermic reactions cool the syngas and increase its heating value due to the increase of CO and H₂.

Source: Destec, 1998. The Wabash River Coal Gasification Repowering Project

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圖 III.3-8

Model Description

Gasification CFD Model

- Fluid flow, heat and mass transfer, and chemical kinetics.
- Eulerian-Lagrangian multiphase method:
 - Continuous gas phase with reactions.
 - Discrete Phase Model (DPM) for coal slurry (performed at every 50th iteration of the fluid phase calculation)
 - Coal particle processes:
 - Particle injections
 - Inert heating
 - Moisture release
 - Devolatilization
 - Char combustion and gasification
- Temperature of 2500K was patched in gasifier to initialize reaction.

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圖 III.3-9

Model Description

Methodology & Equations

- The CFD solver: **ANSYS FLUENT**
- Turbulence: **Standard k-ε Model**
- Radiation: **P1 Model**
- Two phases: **Discrete Phase Model**
- Reaction: **Finite-rate/Eddy-dissipation rate Model**

Reaction	n	k = A T ⁿ exp(-E/RT)	
		A/(kgm ² Pa ⁿ s)	E/(kJ/kmol)
Heterogeneous			
C(s) + 1/2 O ₂ → CO	0	0.052	6.19E+07
C(s) + CO ₂ → 2CO	0	0.0732	1.12E+08
C(s) + H ₂ O → CO + H ₂	0	0.0782	1.15E+08
Homogeneous			
CO + 1/2 O ₂ → CO ₂	0	2.20E+12	1.67E+08
CH ₄ + 2O ₂ → 0.3585H ₂ + 0.264CO + 0.436CH ₄	0	eddy-dissipation rate	
C ₂ H ₆ + 3O ₂ → 6CO + 3H ₂	0		
CH ₄ + 1/2 O ₂ → CO + 2H ₂	0		
CO + H ₂ O → CO ₂ + H ₂	0	2.75E+02	8.38E+07

Source: Sliem, A. and T. Wang. Comparison of instantaneous, equilibrium, and finite-rate specification models in an entrained-flow coal gasifier. In International Pittsburgh Coal Conference, 2009. Pittsburgh, USA.

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圖 III.3-10

Model Description

Boundary Condition

- 491,687 computational cells
- Illinois #6 coal
- Operating pressure: 28 atm
- Adiabatic wall.
- Rosin-Rammler distribution

	Mass Flow rate	Temperature
Coal Slurry	39.7 kg/s	411 K
Oxidant	22.9 kg/s	450 K

O ₂ /Coal	0.918
Coal slurry concentration	0.67

Source: NETL, 2005. CAPE-OPEN Integration for Advanced Process Engineering Co-Simulation.

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圖 III.3-11

Model Description

Base Case & Grid Sensitivity

- The outlet results are compared with the reference data.
- Except for H₂O has a 6.52 percentage point difference, the differences of other outlet gas species are below 3 percentage points.
- The differences of the outlet species and temperature between the cases of 0.49M and 1.05M are less than 3%.
- Since the objective is to examine the global gasification behavior, the 0.49M grid is used for further studies.

Outlet Results		Base case	Ref.*
Mole Fraction (%)	CO	38.59	35.90
	H ₂	23.26	22.90
	CO ₂	11.56	12.20
	H ₂ O	17.43	23.90
	N ₂	3.00	2.00
T(K)	CH ₄	4.01	1.70
		1865	-

Cell number		0.12M	0.31M	0.49M	1.05M
Mole Fraction (%)	CO	38.26	38.64	38.59	38.36
	H ₂	23.21	23.3	23.26	22.69
	CO ₂	11.86	11.49	11.56	11.76
	H ₂ O	17.39	17.45	17.43	17.90
T(K)		1876	1863	1865	1910

* NETL, 2005. CAPE-OPEN Integration for Advanced Process Engineering Co-Simulation.

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圖 III.3-12

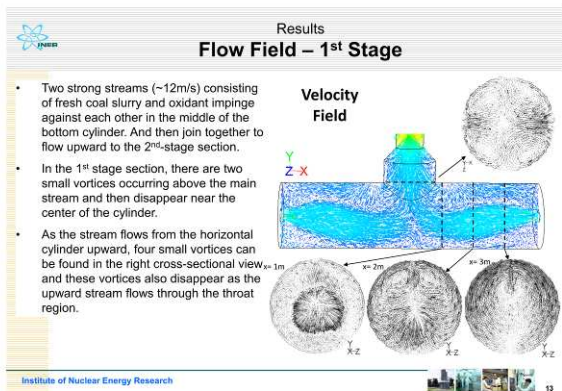


圖 III.3-13

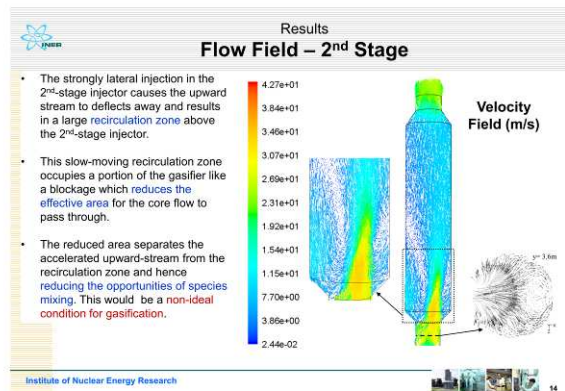


圖 III.3-14

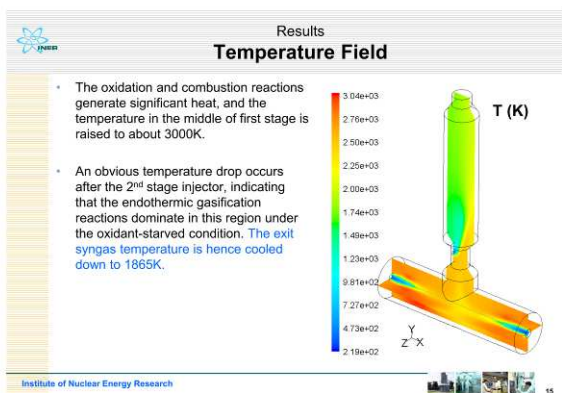


圖 III.3-15

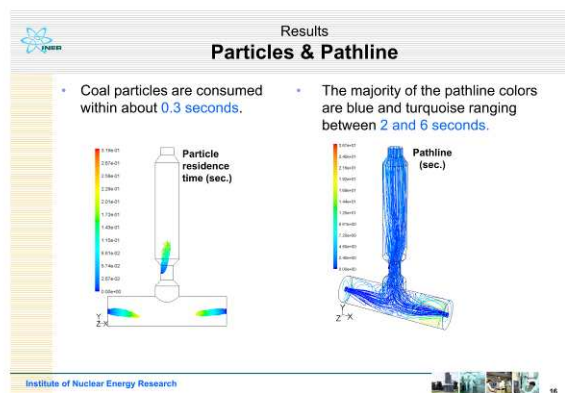


圖 III.3-16

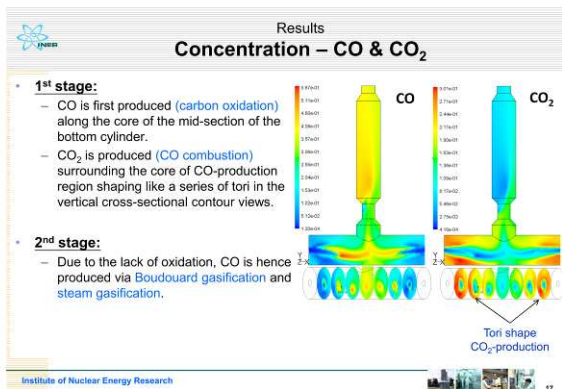


圖 III.3-17

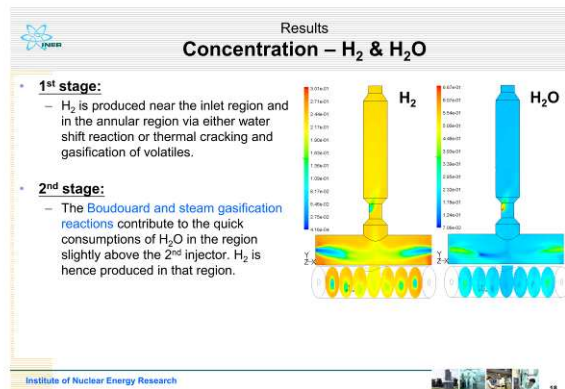


圖 III.3-18

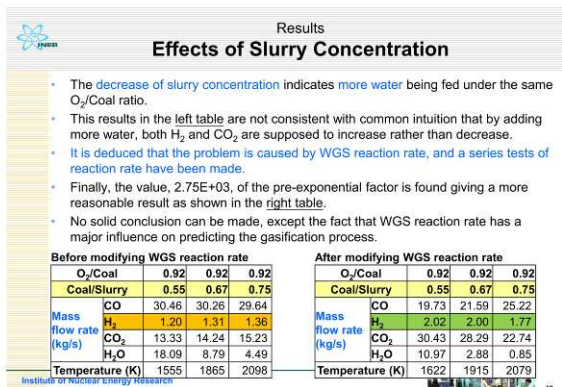


圖 III.3-19

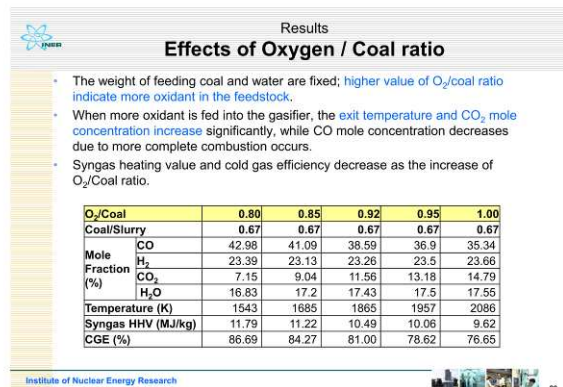


圖 III.3-20

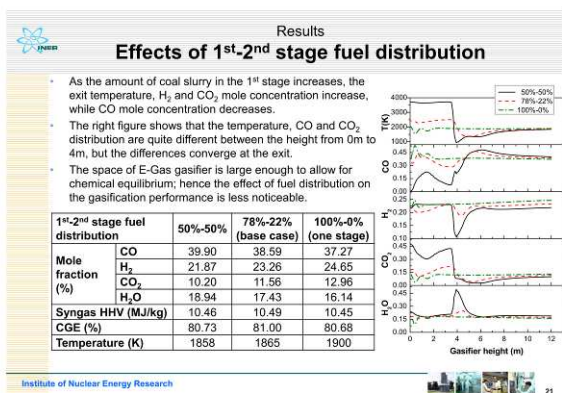


圖 III.3-21

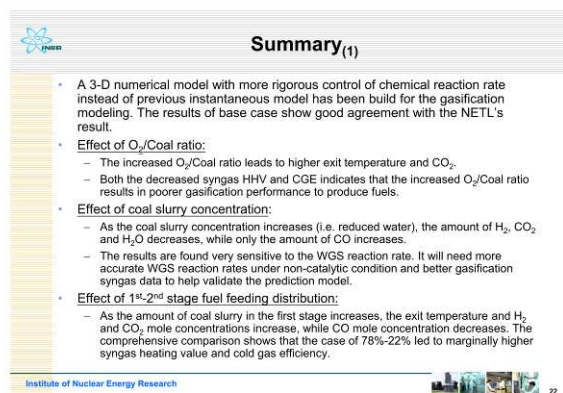


圖 III.3-22

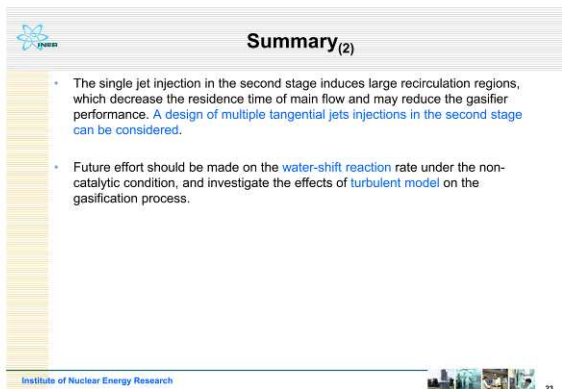


圖 III.3-23

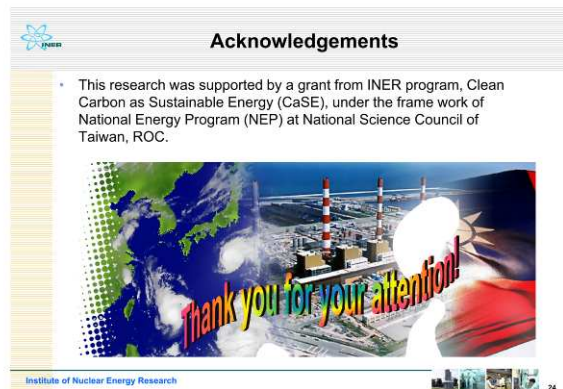


圖 III.3-24

(五) Poster Session 相關圖片

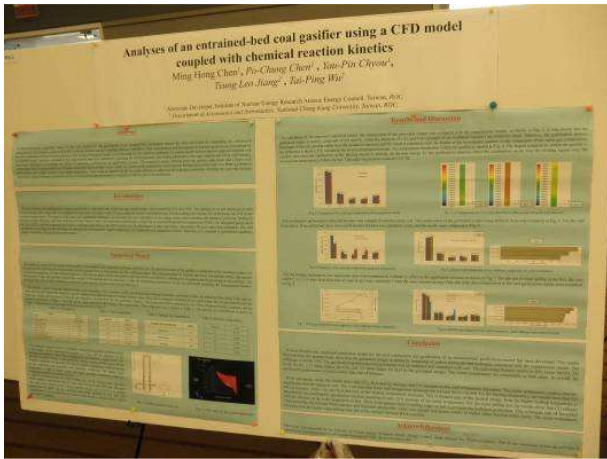


圖 III.4-1



圖 III.4-2



圖 III.4-3



圖 III.4-4

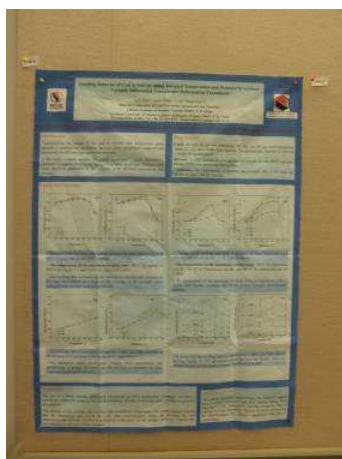


圖 III.4-5



圖 III.4-6