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Interim Report:

Status of the International Energy Agency Annex 11 Subtask B

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DISCLAIMER

International Energy Agency Annex 11, Subtask B – Interim Report

This document is meant to describe the status of the International Energy Agency (IEA), Annex 11 (Integrated Systems), Subtask B (Analytical Tools) effort being carried out by the Member Nations. This includes Canada, Japan, Italy, the Netherlands, Spain, Switzerland, and the United States. The Subtask status is taken as of the close of the Annex 11 Experts' Meeting in Neunburg vorm Wald, Germany April 10-11, 1997.

The goal of this Annex is to identify, compile, and integrate models of hydrogen technology components into system models that will describe overall pathways. Examples would include: PV/electrolysis/pipeline transport/hydride storage/PEM fuel cell utilization or natural gas steam reforming/liquefaction/truck transport/hydrogen refueling station. Component models are developed by the Member Nations and integrated into the desired overall system. Subtask B is concerned with identifying and compiling existing component models from Member Nations, or developing these models from data supplied by the Member Nations via Subtask A.

In a meeting of Annex 11 Subtask Leaders and the Operating Agent in Stüttgart, Germany in the summer of 1996, it was decided to approach the modeling of the various components by assigning a team to each component. The team would consist of a team leader and support members who would provide model development, data, and model validation. This approach was implemented at the Annex 11 Experts' Meeting in Tokyo, Japan in October 1996. The makeup of the Technology Teams and their respective component assignments appears in Table 1.

ASPEN Plus® was selected as the modeling platform of choice, and this software tool was only available within the group at ECN (Netherlands), and at NREL (USA). It was thus decided that these two organizations would perform the actual model construction after receiving the required input from the Technology Team leaders.

Also, at the Experts' Meeting in Tokyo, it was decided that in order to keep component modeling moving along smoothly, half the models would be due to the Subtask B leader by January 31, 1997, and the remainder by March 15. Based on this, the Teams were asked to identify delivery date for each of the models for which they had responsibility.

The initial responses from the Teams are shown in Table 2

Due to various difficulties several of the models slipped beyond the promised Table 2 dates, so that prior to the meeting, the only completed component models delivered to Subtask B were:

• Coal Gasification	Netherlands (Team Lead)	Netherlands (Model supplier)
• Biomass Gasification	U.S.	U.S.
• Biomass Pyrolysis	U.S.	U.S.
• High Pressure Pipeline	U.S.	U.S.
• Low Pressure Pyrolysis	U.S.	U.S.

Short descriptions of these newly constructed models follow:

Coal Gasification

This effort models the production of hydrogen from coal. Briefly, a coal-water slurry and oxygen are reacted in a Texaco-type gasifier. The resulting syngas is cooled, scrubbed, and run through high and low temperature shift reactors. The product hydrogen is purified by pressure swing adsorption. The electricity requirement for the system is satisfied via a steam turbine fueled by process heat-generated steam.

Biomass (wood) Gasification

This model is based on the Battelle indirect-gasifier. Dried wood chips are fed into the gasifier where they are gasified using steam as the fluidizing gas, and hot sand as the heat source and bed material. The resulting syngas is steam-reformed and then run through high and low temperature shift reactors. The product hydrogen is purified by pressure swing adsorption.

Biomass (wood) Pyrolysis

A series of vortex reactors are used to convert dried wood chips to pyrolysis oils. The oils (biocrude) thus formed are removed to a centralized location where they are steam-reformed, and then run through high and low temperature shift reactors. The product hydrogen is purified by pressure swing adsorption. The model is based on experimental work being performed at NREL.

High Pressure Pipeline

This model consists of pipeline segments each linked to a compressor. Hydrogen gas is compressed and run through a pipeline to a point where its pressure has dropped by an amount set by the allowable compression ratio. At that point, a compressor raises the pressure back to the original value. The process is repeated as many times as necessary.

Low Pressure (Distribution) Pipeline

This model calculates the length of a low-pressure pipeline that will correspond with a given pressure drop. The model includes a letdown valve and liquid separator to allow interfacing with higher-pressure pipelines.

A second group of models were completed just prior to the meeting and were delivered to the Subtask B Leader at the Neunburg meeting:

• NG Reforming	U.S.	U.S.
• Chemical Storage	Netherlands	Netherlands

- MeOH Transport Netherlands Netherlands

Model descriptions follow:

NG Reforming
The model for steam reforming of natural gas is based on information provided by SRI International. It includes a step for desulfurization of the natural gas using zinc oxide, a high-temperature steam-reforming step, high- and low-temperature shifts, and purification by pressure-swing adsorption.

Chemical Storage
The Netherlands representatives supplied a model for storing hydrogen in methanol. The model, its data taken from the literature, simulates the synthesis of methanol from hydrogen and syngas, followed by the purification of the methanol via distillation. The syngas is composed primarily of CO, CO_2, and hydrogen. The synthesis process includes gas compression to about 100 atm., preheating to about 220° C, and reaction at 260° C. The distillation process includes a low-pressure flash to remove some of the dissolved gases, a topping column to remove the remaining dissolved gases, and a refining column to remove water.

MeOH Transport
The methanol transport model, based on data from the Institute of Applied Energy in Tokyo, Japan, simulates the use of a sea tanker for the transport of methanol, and includes the loading and unloading of the tanker.

The PV/Wind/Grid/Electrolysis model, being provided by Spain, the U.S., and Canada was expected to be completed shortly after the meeting.

Other models are being worked on. Some of the problems associated with model completion of some of the other components include:

- The only existing component model is in an integrated package not applicable to hydrogen, and must be decoupled.
- Models exist, but are built off proprietary data. Model must be modified to make it non-proprietary before release.
- Component manufacturers consider data and modeling inputs proprietary and will not provide information for the modeling effort.

An overall status of the component models as of the close of the Neunburg meeting, as broken down by technology area, is shown in Tables 3-6. These include, in cases, the revised completion dates from the original January 31/March 15 options. As can be seen, the models completed or expected to be completed shortly are primarily in the source/production or transport technology areas. No storage or utilization component models have been completed yet. Thus, while subsystems (such as PV-electrolysis) can be integrated, the information needed to be provided to Subtask C for overall integrated systems is still deficient.

Table 1. Technology Team Assignments

Category	Process	Canada	Italy	Japan	Netherlands	Spain	Switzerland	USA
1-Production	*Grid-electrolysis*	M		D			**M,D**	
1-Production	*Wind-electrolysis*							M,D
1-Production	*PV-electrolysis*	M	D	D		D	**M**	M
1-Production	*NG-reforming*	M,D						**M,D**
1-Storage	*Compressed-HP*	M	D			D		M
1-Storage	*Compressed-LP*	M	D			**D**		M
1-Storage	*Metal hydrides*	**M**	D	m		D		D
1-Storage	*Liquefaction and tank*	M		**m,D**				
1-Transport	*Ship transport*			**M,D**				
1-Transport	*x% in natural gas*							
1-Transport	*Pipeline-HP*	M,D						M,D
1-Transport	*Pipeline-LP*	M,D						**M,D**
1.5-Transport	*Tank truck*							M,D
1-End Use	*PEMFC*	**M**	D		m		D	D
1-End Use	*PAFC*	M		D		**D**	D (Finland)	

M=model supply
m=model modification/input-output results
D=data

Category	Process	Canada	Italy	Japan	Netherlands	Spain	Switzerland	USA
2-Production	*Hydro-electrolysis*							
2-Production	*Biomass gasification*				M			**M,D**
2-Production	*Biomass pyrolysis*							**M,D**
2-Storage	*Chemical (MeOH)*	M		D				
2-Storage	*Chemical hydrides*						**M,D**	
2-Transport	*MeOH-transport*							
2-End Use	*SOFC*				m			
2-End Use	*MCFC*				m			m,D
2-End Use	*Gas turbines*				M			
3-Production	*Coal gasification*				**M**			

M=model supply
m=model modification/input-output results
D=data

Table 2
Initial Responses from Technical Teams on Dates for Compliance with Component Model Inputs

Team Lead	Component	Date Promised
Canada:	Electrolysis	January 31
	Compressed Gas (High Pressure)	March 15
	Compressed Gas (Low Pressure)	March 15
	PEM Fuel Cells	January 31
Japan:	Liquefaction	March 15
	Tank Truck	March 15
	Transport Tanker	March 15
Netherlands:	Chemical Storage (MeOH)	January 31
	MeOH Transport	January 31
	Coal Gasification	March 15
Spain:	PV	March 15
	Phosphoric Acid Fuel Cells	March 15
Switzerland:	Chemical Hydrides	March 15
United States:	Biomass Gasification	January 31
	Biomass Pyrolysis	January 31
	High Pressure Pipeline	January 31
	Low Pressure Pipeline	January 31
	Wind	March 15
	Natural Gas Reforming	March 15
	Metal Hydrides	March 15
	Solid Oxide Fuel Cells	March 15
	Molten Carbonate Fuel Cells	March 15
	Gas Turbines	March 15

Table 3. Status of Component Model Development

Source and Production Components

Technology	TT Lead	TT Support	Date Promised	Status
Electrolysis	Canada	IT,JP,SP,SW,US	3/19	Completion Imminent Integrated with PV, (Wind)
Wind	USA	IT	3/19	Completion Imminent (Integrated with Electrolysis)
PV	Spain	CN,IT,JP,SW,US	3/19	Completion Imminent (Integrated with Electrolysis)
NG Reforming	USA	CN	3/27	Completed
Biomass Gasification	USA	NE	1/31	Completed
Biomass Pyrolysis	USA		1/31	Completed
Coal Gasification	Netherlands	US	1/31	Completed

Table 4. Status of Component Model Development

Storage Components

Technology	TT Lead	TT Support	Date Promised	Status
High Press CG	Canada	NE, SP	3/15	Do Not Have
Low Press CG	Canada	IT, NE	3/15	Do Not Have
Metal Hydrides	USA	IT,SP,JP	4/2	Do Not Have
Liquefaction	Japan	NE,US	3/15	Have Data Only
Chemical Storage (MeOH)	Netherlands	JP	4/10	Completed
Chemical Hydrides	Switzerland	NE	4/10	Do Not Have

Table 5. Status of Component Model Development

Transport Components

Technology	TT Lead	TT Support	Date Promised	Status
Transport Tanker	Japan	NE	3/15	Have Data Only
High Press Pipeline	USA	CN	1/31	Completed
Low Press Pipeline	USA	CN	1/31	Completed
Tank Truck	Japan	NE,US	3/15	Have Data Only
MeOH Transport	Netherlands	JP	4/10	Completed

Table 6. Status of Component Model Development

Utilization Components

Technology	TT Lead	TT Support	Date Promised	Status
Blend in NG	-	CN	?	?
PEMFC	Canada	IT,NE,SW,US	3/15	Do Not Have
PAFC	Spain	JP,SW,US	3/15	Do Not Have
SOFC	USA	CN,NE,SW	3/15	Needs Editing
MCFC	USA	JP,NE	3/15	Needs Editing
Gas Turbines	USA	JP	After Meeting	Do Not Have