DOE Hydrogen Program

IEA Hydrogen Task 18: Evaluation of Integrated Demonstration Systems

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122 West

Project ID #SAP3

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Overview of IEA Integrated Systems Project (Task 18)

Timeline

- Project start date:
  January 1, 2004
- Project end date:
  December 31, 2009
- Percent complete: ~50%

Barriers Addressed from MYPP

- Tech validation
  - Storage
  - Hydrogen Refueling Infrastructure
  - Codes and Standards
  - Hydrogen from Renewable Sources
  - Hydrogen and Electricity Co-Production
- Safety, codes and standards
  - Conflicts between domestic and international C&S
  - Large Footprint requirements for hydrogen fueling stations
- Systems analysis
  - Lack of consistent data, assumptions and guidelines
  - Lack of consensus on modeling tools

Budget

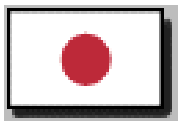
- Total project funding
  - DOE share: $500K
  - Contractor co-share: contributed labor (~$100K)
  - International partners: 36 FTE
- Funding received in FY06: $70K
- Funding for FY07: $125K

Partners / Collaborators

- International Energy Agency, Hydrogen Implementing Agreement
  Task 18 members:
  - Eleven countries
  - European Commission
- Sandia National Laboratories (Lutz, Stewart)

Participants of IEA Hydrogen Task 18

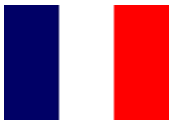
Canada
Natural Resources Canada



Japan
AIST Laboratory

Italy
ENEA

Iceland
Icelandic New Energy



France
CEA

European Commission
Joint Research Center

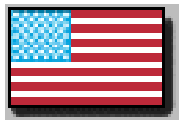
The Netherlands
ECN

Norway
IFE

Spain
INTA

Sweden
EO.N.

United Kingdom
EA Technology



United States
Department of Energy

Denmark
Gas Technology Center

New Members: Austraila, Germany, Greece, New Zealand, Taiwan

Objectives of IEA Hydrogen Task 18

•Operate international working group to address hydrogen technology integration in member countries.

•Establish database of international hydrogen development activities, capabilities and demonstrations

•Evaluate hydrogen systems performance, cost, safety, and Codes and Standards permitting policies

•Participate in the International Energy Agency study: “Where will the hydrogen come from?”

Approach => Collaboration

- Members of IEA Hydrogen Implementing Agreement Task 18 work collaboratively within three subtasks:
  - Subtask A: Information Base Development
  - Subtask B: Demonstration Project Evaluation
  - Subtask C: Synthesis and Lessons Learned
- **U.S. DOE Sponsors the Operating Agent; Subtask Leaders are sponsored by Canada, Norway and the Netherlands**
- Members/experts meet twice per year to review progress; ongoing collaboration is carried out electronically
- Members deliver progress reports annually

Approach => Collaboration

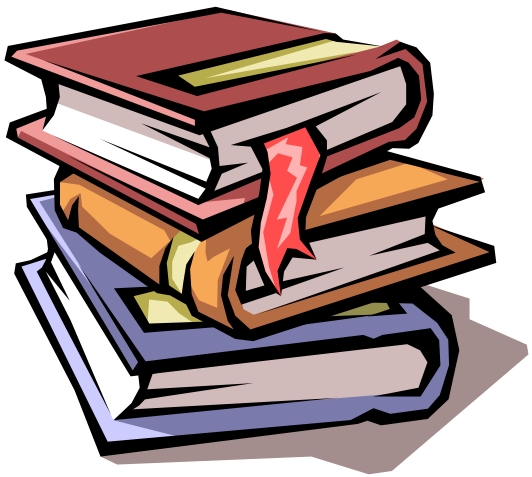
- Subtask A: Members Responsibilities:
  - Deliver to searchable web portal national studies and requested data
- Subtask B: Members Responsibilities:
  - Work as a group to establish a list of desired data for each project
  - Bring to the group data from that country's project
  - Clarify with the data provider any limitations on data release or use
  - Make use of appropriate modeling & analysis tool for selected projects
  - Provide assessments & evaluations of the project based on the analysis results
- Subtask C: Members Responsibilities:
  - Contribute Case Studies
  - Synthesize Lessons Learned
  - Provide input on status of integration

Technical Accomplishments/ Progress/Results

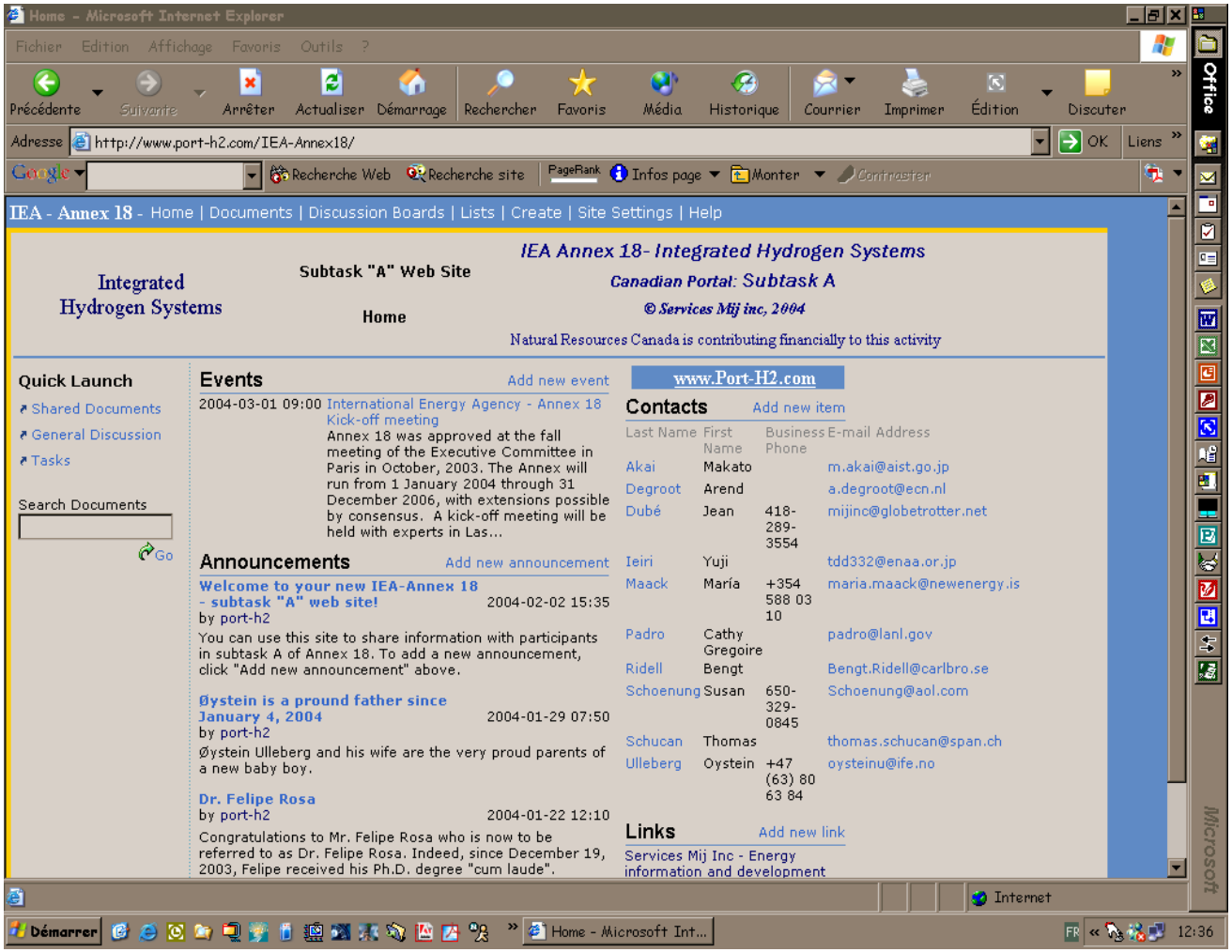
- Subtask A: Database contains over 200 documents
  - Includes Hydrogen resources database
- Subtask B: Analysis of 7 demo projects completed:
  - Spain - Fuel Cell Research Project for Telecommunications
  - UK - Hydrogen and Renewables Integrations (HARI) project
  - Sweden - Malmö bus refueling station
  - Japan - Reversible fuel cell system
  - Iceland - Bus refueling station
  - US - combined fuel and electricity system
  - Canada - vehicle refueling station
- **All assessments include documentation of safety, codes and standards, and permitting requirements**
- Case studies: 3 completed within the last year
  - Hydrogen and Renewables Integration project (UK)
  - H2 Truck (Denmark)
  - PEM Fuel Cells in Real Conditions - EPACOp (France)

Subtask A: Information Base Development

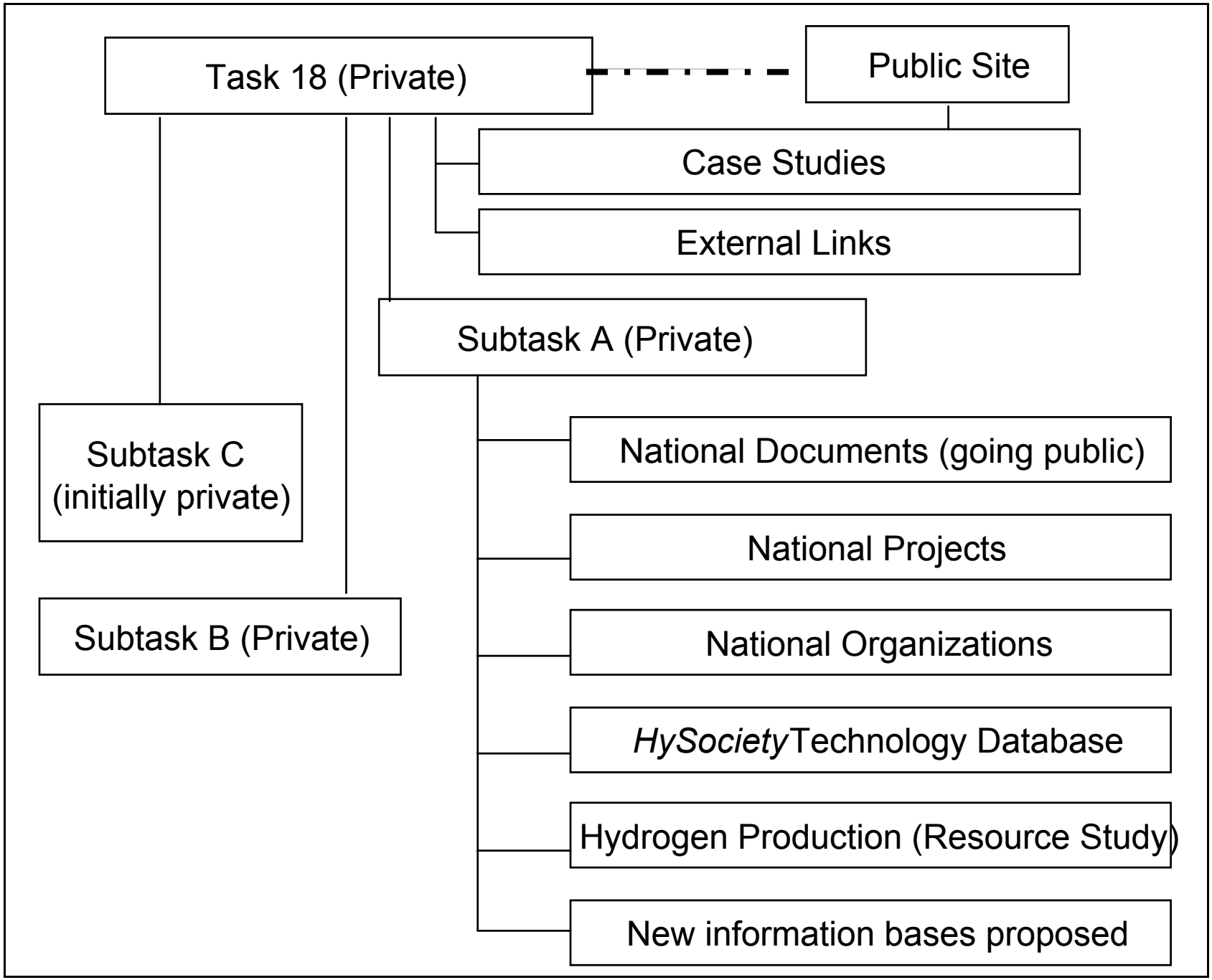
- National plans
- Demonstration progress
- Hydrogen resources
- Vendors
- Utilization rates
- Geographic information
- Refueling projections
- Costs
- Infrastructure
- Codes and Standards
- Economic analysis



Annex 18 website: Searchable portal



Subtask A: Information Bases



Subtask A – Information bases

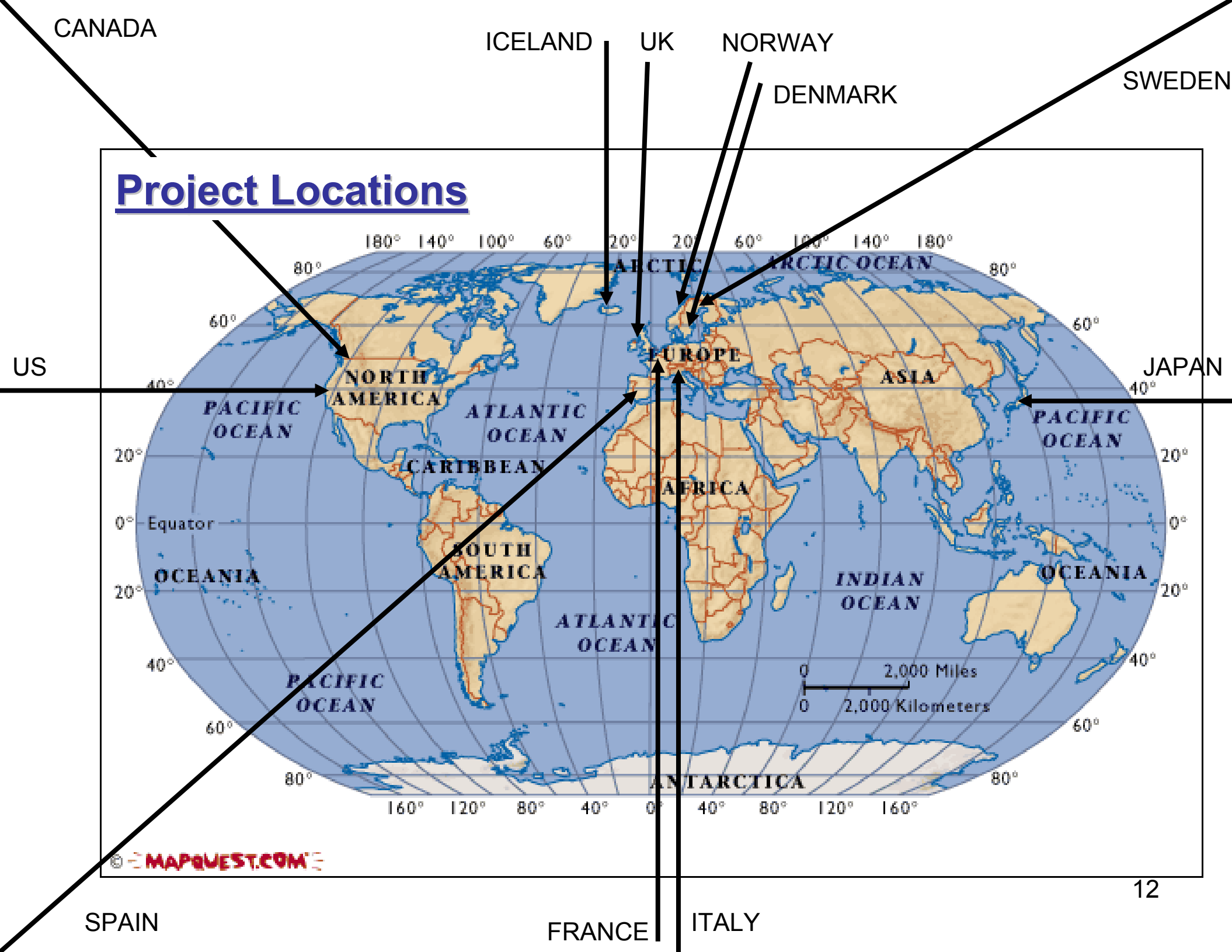
Current Postings in Subtask A Information Base
200 postings on National Documents sub website: • 118 Searchable summaries • 24 IEA Case Studies in Word format
105 National Organizations
25 National Projects
Links to external databases and websites
This password accessible website contains 426 Megs of information, has received 3443 visits and 10,495 pages have been examined.

National Documents Sub-Website went public December 31, 2006, through link on public website.

Task 18 Project Portfolio

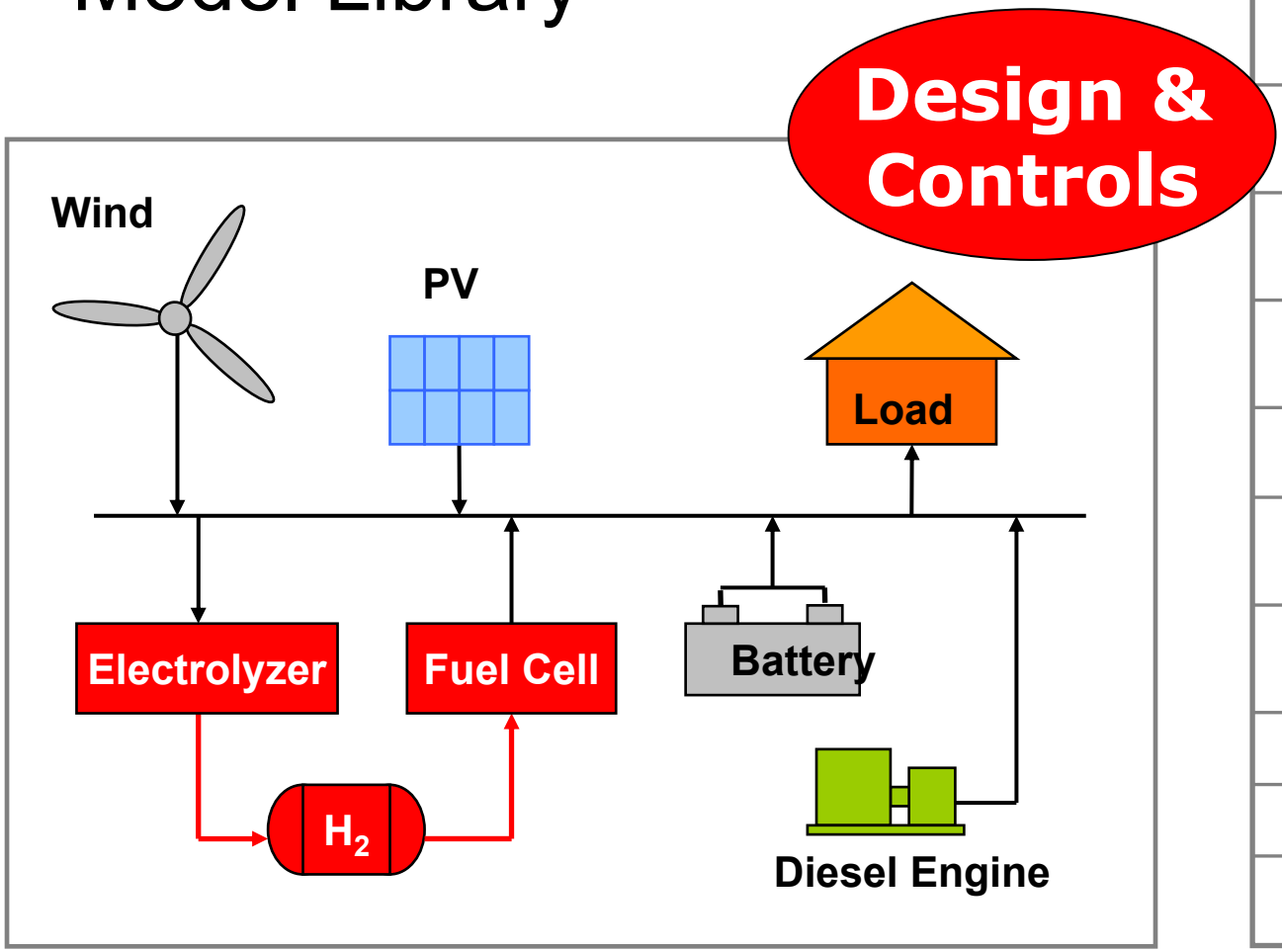
Country	Projects	Location	Modeling focus	Evaluation status
Refueling Stations				
Sweden	Hydrogen filling station (re grid/electrolysis)	Malmö	System sizing	Complete
Iceland	Hydrogen filling station (grid/electrolysis)	Reykjavik	Electrolyzer performance	Complete
Canada	Hydrogen filling station (grid/electrolysis)	Vancouver	Compressor performance	In progress
Grid-connected or stand-alone power systems				
Spain	PV/MH- telecom showcase (RE)	Madrid	Storage sizing	Complete
Japan	Regenerative PEM FC-power system (grid)	Aichi	Storage thermal control	Complete
UK	RE/H2-project	Loughborough	Economic performance	Completing
Italy	Hydrogen from the Sun	Brunate	System efficiency	Phase 2
Combined fuel and electricity generation				
USA	Hydrogen energy/refuelling station (NG)	Las Vegas	System performance	Complete
USA	Hydrogen power park (RE)	DTE or HI	Performance, economics	Phase 2
Infrastructured emonstrations				
Denmark	Natural gas/ hydrogen pipeline, boiler	Copenhagen	Economics	In negotiation
Residential heat and power				
France	Building fuel cell evaluation	5 sites	Fuel cell / system performance	Case Study
Other Potential Phase 2 projects				
New Zealand	Renewable hydrogen at remote site	Totara Valley	Renewables integration	Phase 2
Spain	Renewable hydrogen for desalination plant	Canary Islands	System sizing and optimization	Phase 2
Germany	Refueling station	Munich or Berlin	Station sizing and economics	Phase 2

Project Locations



HYDROGEMS

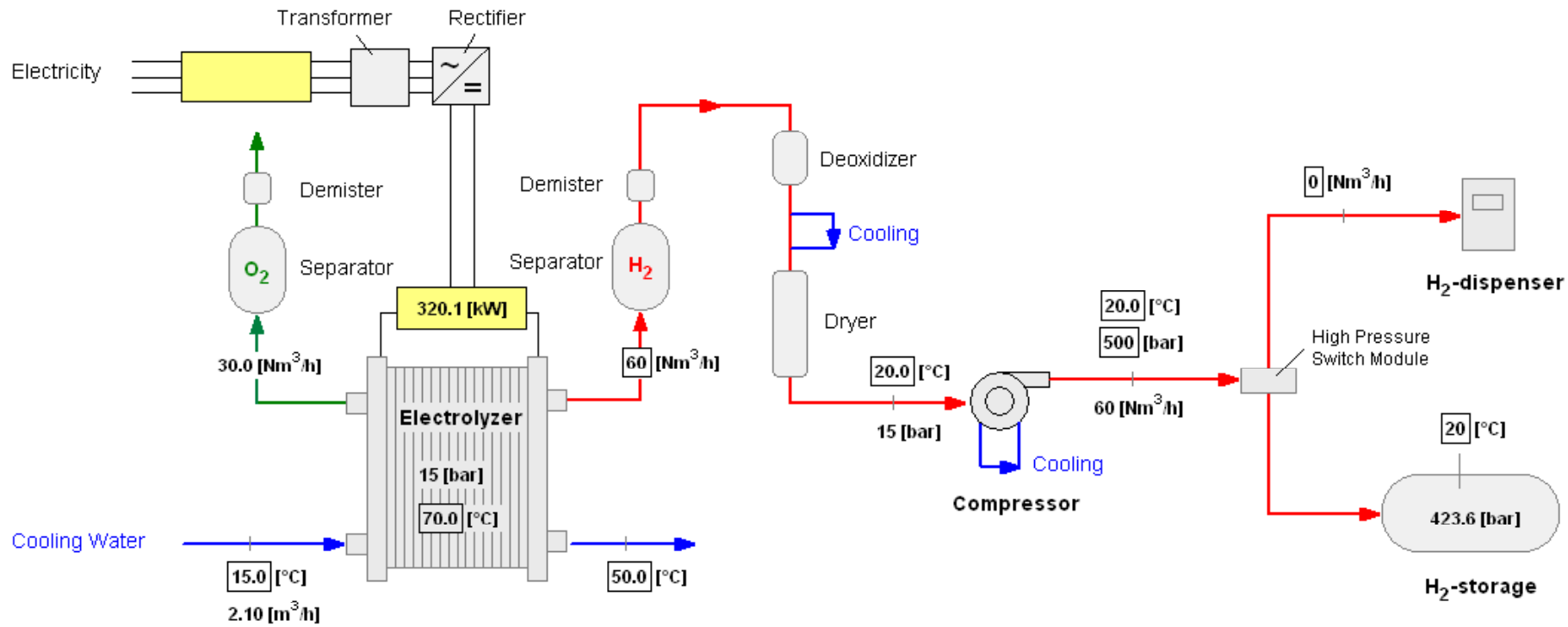
- RE/H_2 System Simulation Model Library



	H Y D R O G E M S HYDROGen Energy ModelS
	Photovoltaics
	Wind Turbines
	Water Electrolysis
	Fuel Cells
	H_2 Gas Storage
	Metal Hydrides
	Batteries
	Compressors
	Power Conditioning
	Diesel Engines

www.hydrogems.no

Hydrogen Station Simulator



Warnings

No H2-storage pressure warnings

Electrolyzer

P_{ely} = 320.1 [kW]
$Q_{ely,cool}$ = 85.1 [kW]

E_{ely} = 5.34 [kWh/Nm³]
η_{ely} = 65.24 [%]
I_{ely} = 1546.7 [A]
U_{ely} = 207 [V/stack]
U_{cell} = 2.070 [V/cell]
$i_{density}$ = 71.8 [mA/cm²]

Compressor

P_{comp} = 8.275 [kW]
$Q_{comp,cool}$ = 12.5 [kW]

$Q_{comp,aftercool}$ = 4.2 [kW]
$Q_{comp,intercool}$ = 8.3 [kW]
$T_{comp,high}$ = 213.3 [°C]

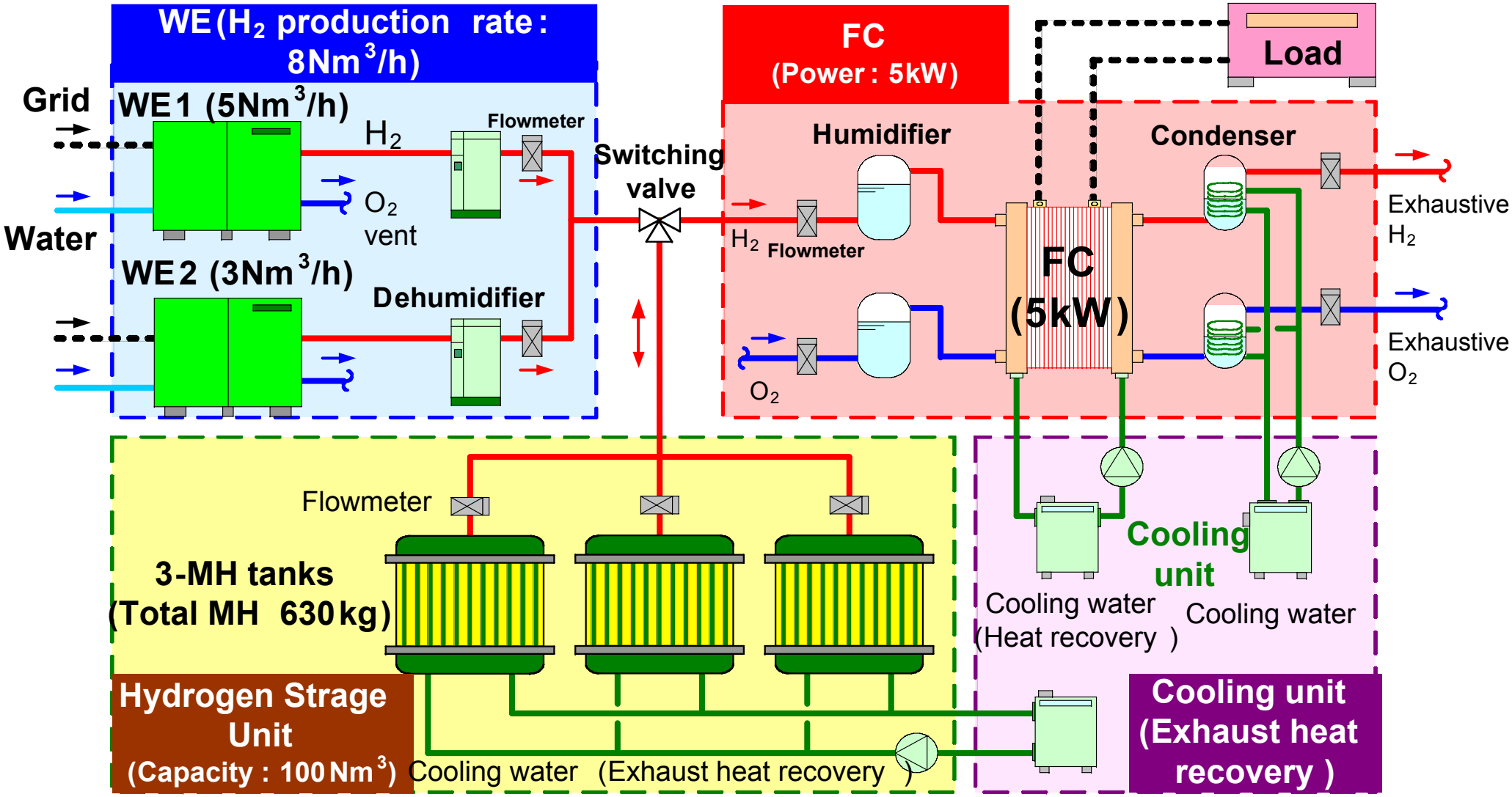
Simulation Setup

$t_{initial}$ = 1
t_{final} = 144 [h]

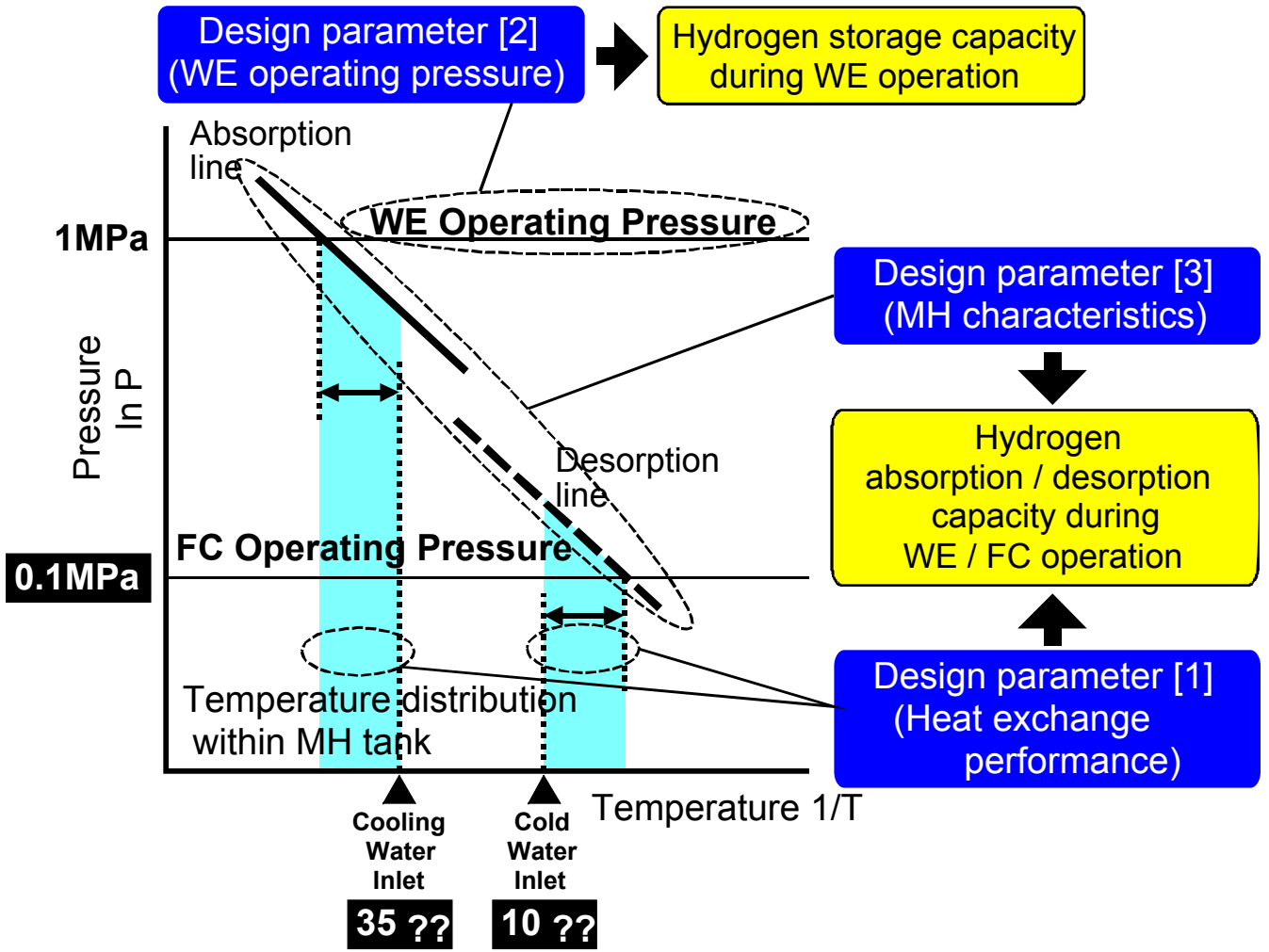
Calculate

Show H2-demand Profile

Integrated H_2 System, Takasago, Japan



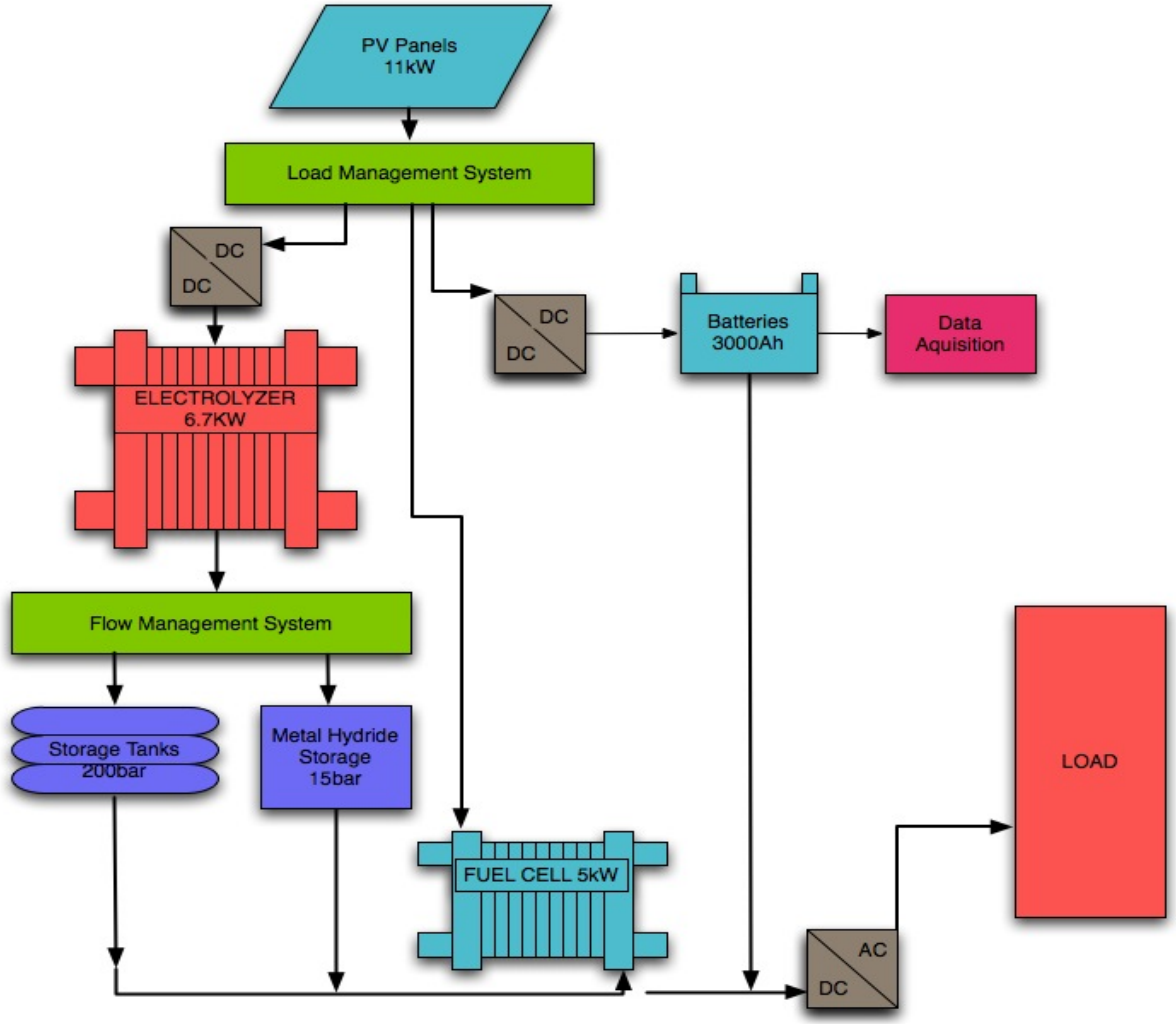
Integrated H_2 System, Takasago, Japan



Objective: to optimize Metal hydride storage thermodynamic performance

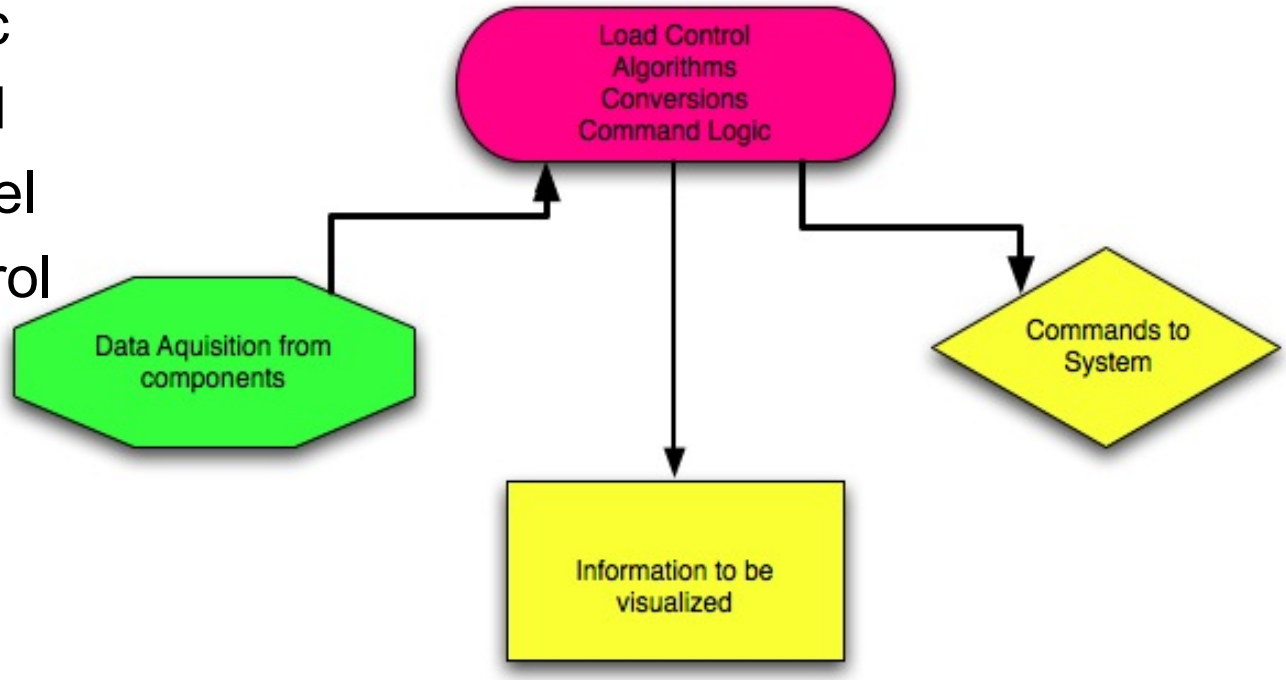
“Hydrogen from the Sun” Ecological house in Brunate, Italy

- 6.7kW High pressure alkaline electrolyser
  - Produces 1NM^3/hr H_2 at 200 bar
- 5kW PEM fuel cell
- 3000Ah battery
- 30Nm^3 Hydrogen stored in metal hydride
- 120Nm^3 Hydrogen in storage cylinders
- 11kW peak power available from photo-voltaic panels

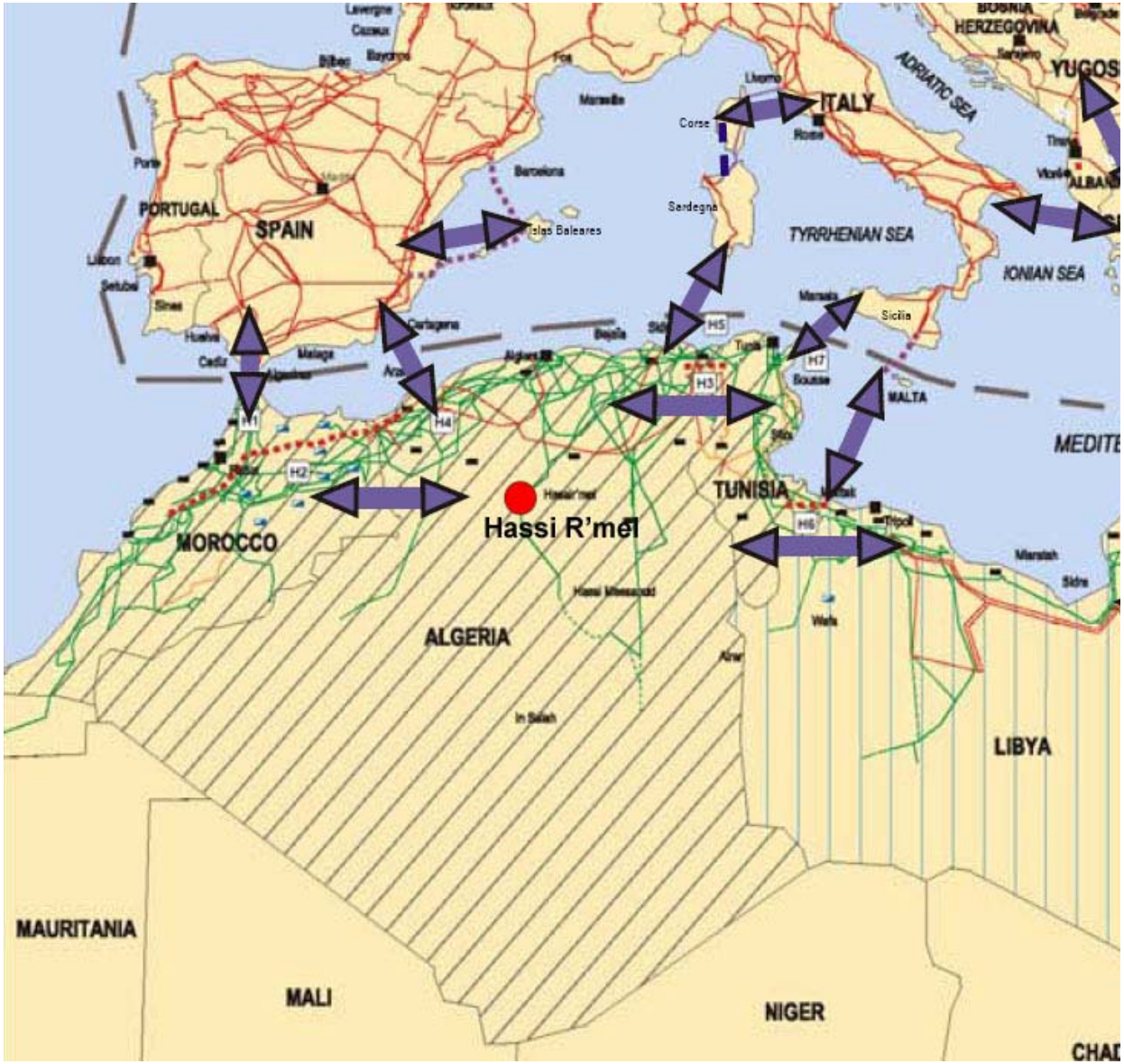


Control Systems/Load Management

- Pseudo-steady-state model developed
- Simple control strategy for fill and empty metal hydride storage required
- Implemented an if-else based strategy to manage loads and power distribution
- Other options
  - Digital Boolean logic
  - Look up table based
  - Open loop test model
  - Closed loop PI control



Phase 2 Analysis: Mahgreb-Europe



Objective: to optimize system size and delivery options

Significant Outcomes of Subtask B
System Studies - Optimization for the Future

I. H_2-refueling stations

1. Expanded service scenario, to 100-200 buses (Malmö)
2. Expanded service, to include more vehicles (Reykjavik)
3. Compressor / dispenser component study; model improvement (Vancouver)

II. Integrated RE/ H_2-energy systems

1. Metal hydride storage optimization (Japan)
2. Techno-economic system design study (HARI, UK)
3. Control strategy optimization (Italy, US, New Zealand)

Spin-off Benefits of Task 18 = Success

1. Optimization of hydrogen systems for the future.
2. Bilateral agreement / project between Norway and Japan on metal hydride storage and thermal control. “Wouldn’t have happened if we hadn’t held a meeting in Tokyo.”
3. Joint project on hydrogen powered ship demonstration is being developed between Iceland and Scotland. A direct result of our meeting in Glasgow.
4. Compressor modeling capability improved by IFE working together with Sandia personnel.
5. Spain: “Thanks to Spanish participation in Annex 18 of Hydrogen Implementing Agreement of IEA we have known other countries activities and initiatives in H_2 and FC and we have had access to technological and logistics problems happened in other countries facilities. Subtask B offers us an extraordinary opportunity to simulate one of our installations and learn about it.”
6. Hydrogems© and other modeling tools are becoming wide-spread among the groups.
7. Due to the success of Task 18, more countries are seeking to join the Task in Phase 2. We welcome them.

Permitting Analysis

Location	Las Vegas, USA	Reykjavik, Iceland	Malmö, Sweden	Vancouver, Canada	Takasago, Japan	Beacon Farm, UK	Brescia, Italy	Ringkobing County, Denmark	5 locations in France
Type of system	Combination fueling station and power plant	Vehicle fueling station	Vehicle fueling station / mixture with natural gas	Vehicle fueling station	Load-leveling power system	Domestic power system	Domestic power system	Hydrogen fuel cell vehicle and filling station	Residential fuel cells
Site description	Limited access parking lot	Publicly accessible Shell station	Publicly accessible bus depot	Fenced laboratory yard	Laboratory building	Garage	Gated estate	Factory floor	Buildings
Hydrogen storage	Compressed gas	Compressed gas (440 bar)	Compressed gas (395 bar)	Compressed gas (450 bar)	Metal hydride tanks	Compressed gas and MH	Compressed gas and MH	MH canisters on truck, Compressed gas in filling station (200 bar)	Natural gas reformer is part of the fuel cell package
Permitting agency	Las Vegas fire department	City	City	City, federal government	Company hazards group	Local fire marshall	Local fire brigade (Province of Como)		European Conformity standards:
Codes applied	Existing building and equipment codes; NFPA 50A for hydrogen storage separation distances	IEC 60079-10 for Electrolyzer; TÜV (Germany), Det NorskVeritas (Denmark), NFPA 50A for hydrogen storage separation distances	Same as for natural gas since the mixture is considered natural gas	SAE J2600 for dispenser SAE J-2719 for fuel quality	Industrial Safety and Health Law, Hydrogen gas guidebook; High Pressure Safety Law; Electric Industry Law			CE certified	-Machinery 98/37/EC -Gas Appliances 90/396/EEC -Pressure Equipment 97/23/EC -Electro-Magnetic Compatibility 89/336/EEC -Explosive Atmosphere (ATEX) 94/9/EC -Low Voltage 73/23/EEC
Safety design	All H2 stored outside with appropriate separation distances	H2 stored outside; electrolyzer components split between hazardous and non-hazardous zones	H2 stored outside	H2 stored outside	Limited access to laboratory building; we must take action of ventilation, ventilation, and the dust removal to prevent the explosion or a fire	H2 storage outside; electrolyzer in separate space with ventilation access to open air	H2 production and storage in separate space with 15 m distance from house	Filling station outside; truck has hydrogen leakage sensors	
Comments	All systems subjected to detailed HAZOP review	"local fire department educated in response plans"	"good public acceptance due to existing familiarity with NG buses"		"Our system meets general regulations for safety, though there is no special regulation only for hydrogen systems in Japan."	"with no proper guidelines, standards or regulations in place for the domestic use of hydrogen, so we had to devise our own"	"at first the fire brigade had a problem, but after a few months they agreed …"	"Standardization is a subject that needs immediate attention, since this already puts restraints on products coming out to the market"	"In the absence of official regulations dealing especially with fuel cell technology, the above-mentioned directives were used.

Future Work: Plans for 2007-2008

Technical progress plans

- Completion of analysis of Hydrogen and Renewables project “The Ecological House” in Brunate, Italy. Joint with Sandia National Laboratories
- Completion of analysis of Hydrogen and Renewables Integration (HARI) project in UK
- Incorporate Hawaii Power Park project into Subtask B; collaboration with Sandia National Laboratories
- Begin new “Lessons Learned” task; trend analysis, synthesis

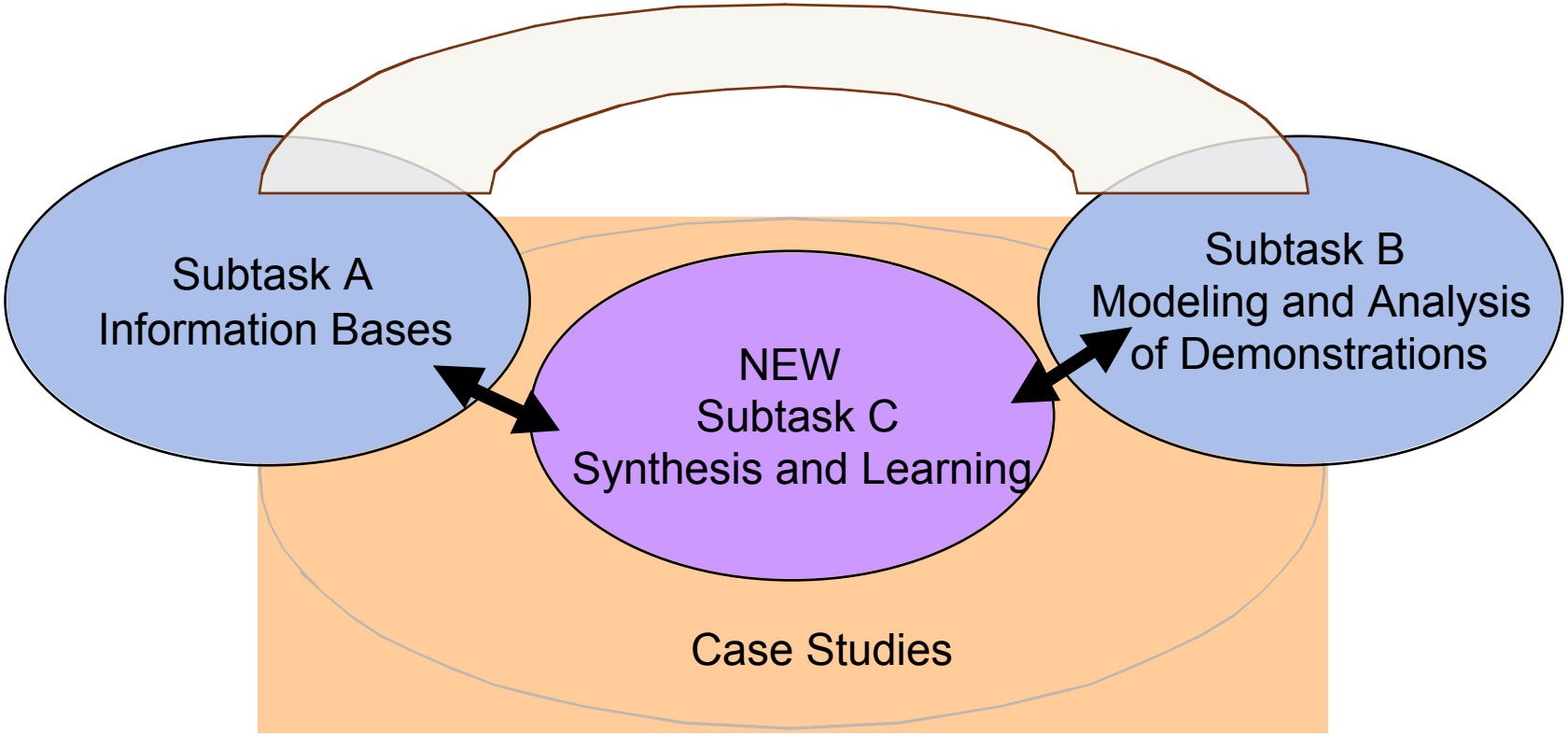
Management plans

- Task Experts meet twice per year; fall 2007 meeting is scheduled for Gran Canaria; spring 2006 meeting is tentatively planned for Hawaii
- Operating agent meets twice a year with Executive Committee; spring 2007 meeting in Switzerland; fall 2007 meeting Italy in November
- Semi-annual reports due in October and April, annual in January

Task 18 Milestone Schedule - Phase 2

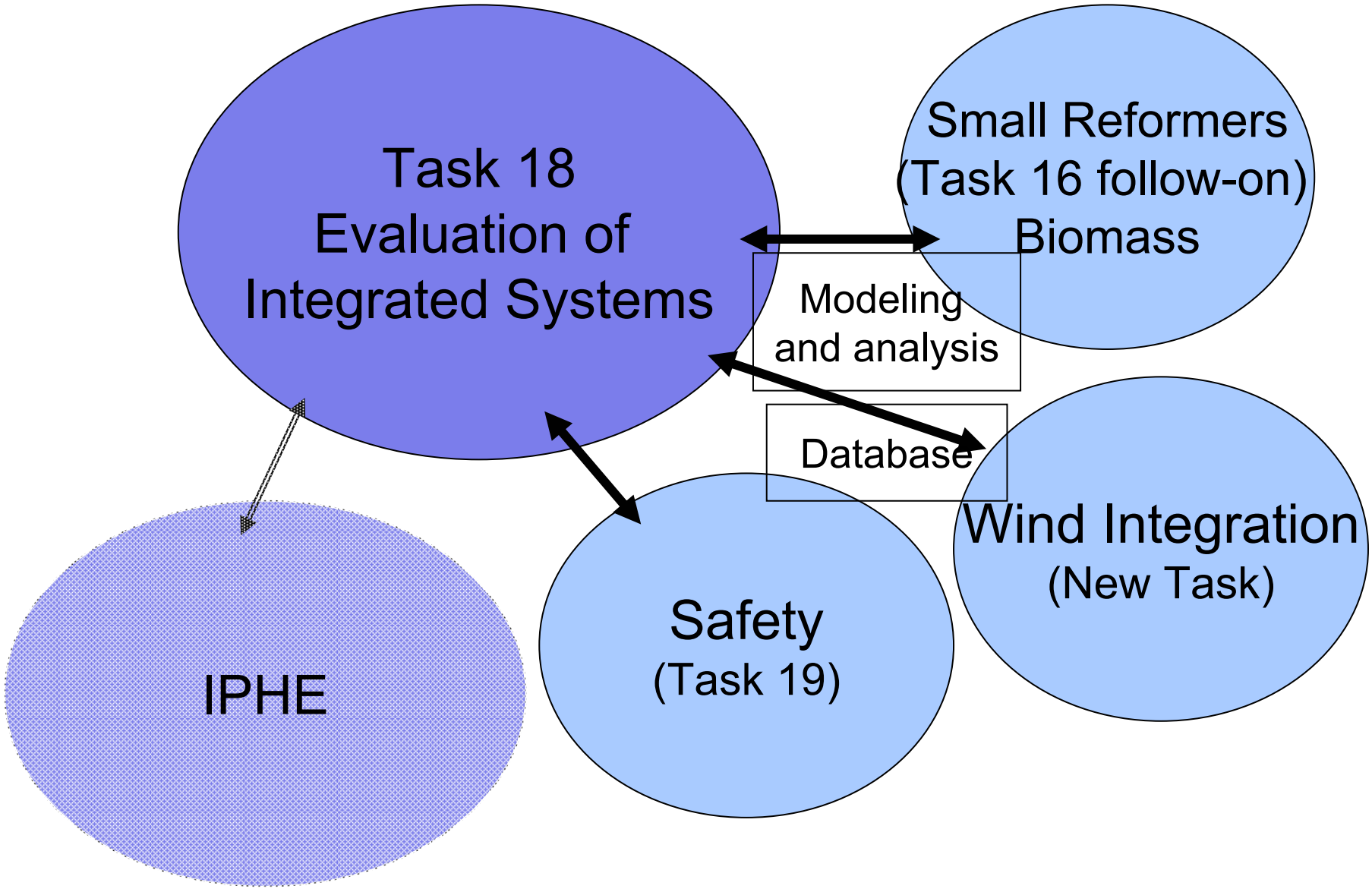
	2007		2008		2009	
Expert Meetings	S07	F07	S08	F08	S09	F09
Subtask A						
Update of info bases and links		X		X		X
New Case Studies and new information bases	X	X	X	X	X	
Public access	X		X		X	
Interim and final report		X		X		X
Subtask B						
Project selection	X		X			
Tools operational	X					
Data gathering	ongoing		ongoing			
Demo evaluation		X		X		X
Final summary report						X
Subtask C						
Planning session	X					
Methodology development		X				
Data gathering	ongoing		ongoing			
Lessons / trend analysis	ongoing		ongoing		ongoing	
Synthesis reports		X	X	X	X	X

Task 18 Phase 2 Structure



- Subtasks A and B continue
  - More analysis capability in Phase 2
- New Subtask C bridges existing elements
  - Lessons learned (case studies and demos)
  - Benchmark assessments
  - Trend analysis (database mining)

Relationship to Other Activities



Summary

Relevance: Technology validation, modeling and analysis, consistent permitting, especially with regard to footprints

Approach: Collaboration among member nations of IEA-HIA; 13 - 16 nations

Technical accomplishments: Database of documents and vendors; Design tools for system optimization; lessons learned

Future Plans: Phase 2 includes new projects; control strategies for economic performance; more lessons learned; and trend analysis