

Progress on Hydrogen Hubs

Jack Robertson and Preston Michie
NW Hydrogen Alliance

Presented at 6th Ammonia Fuel Conference
Kansas City, MO
10/12/2009

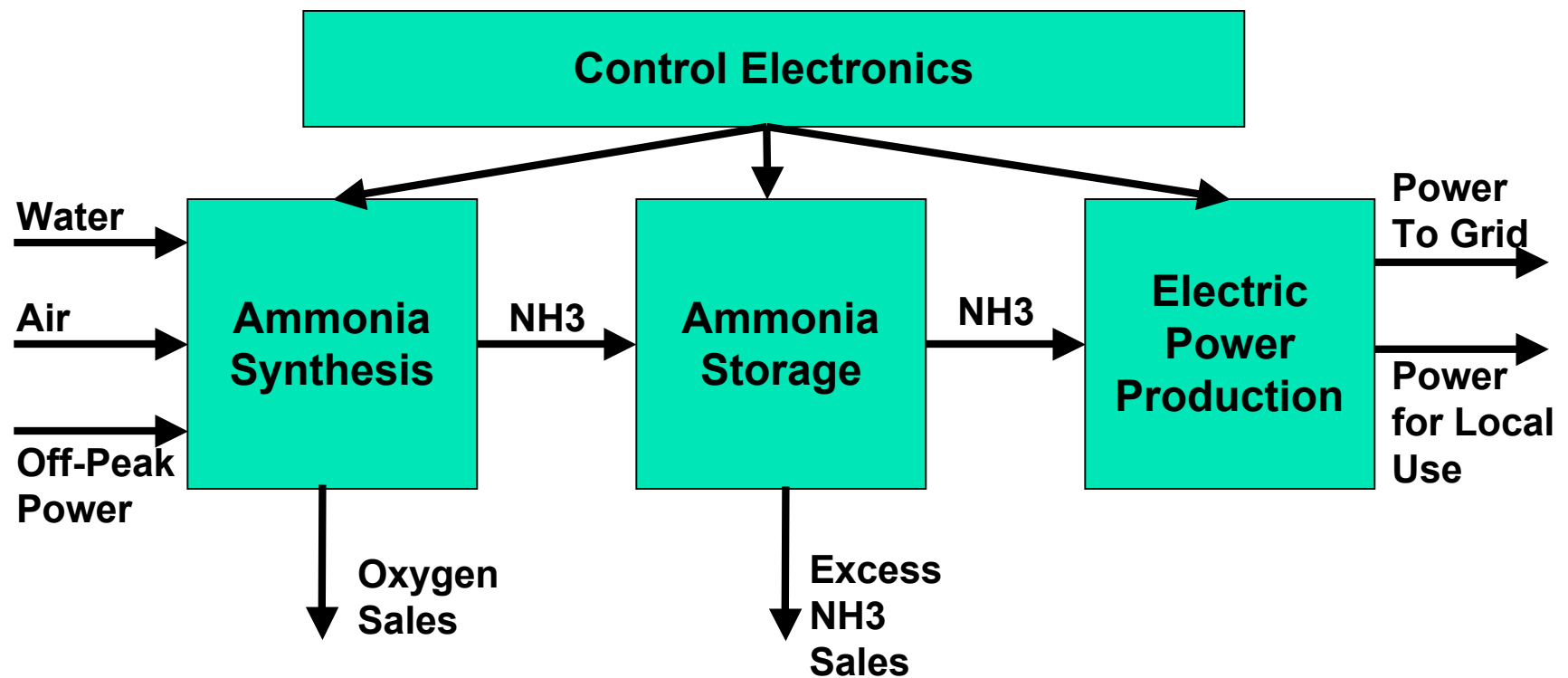
A Hydrogen Hub is ...

- A MW-scale energy storage approach using NH₃ as the storage medium
- A means for producing value-added products while meeting energy storage / generation needs
 - Excess NH₃ for agriculture (or fuel)
 - Pure O₂ by-product stream
- A programmable system load or capacity source
- All the above

H2Hubs Feasibility Study

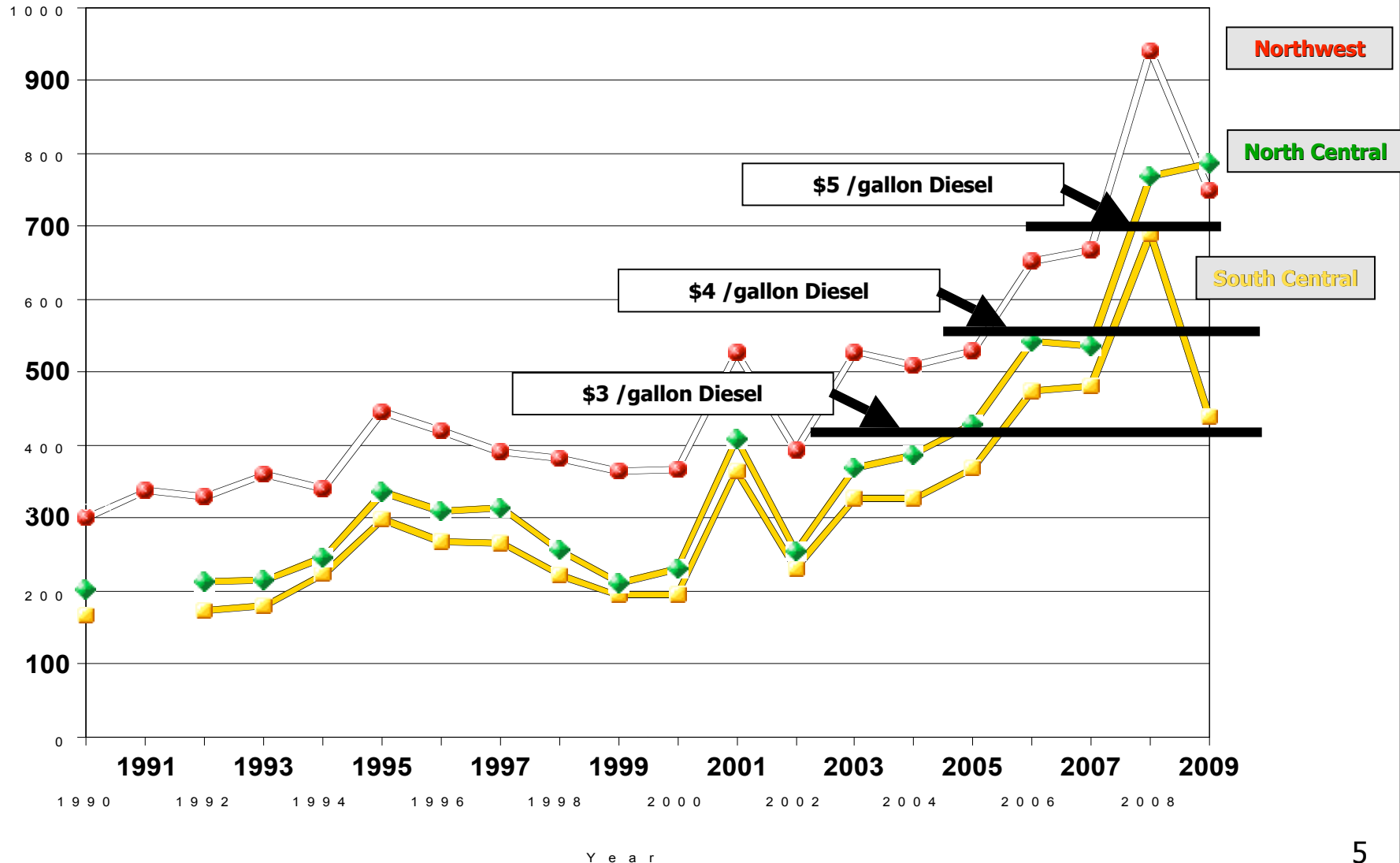
- Sponsored by several NW power companies and Bonneville Power Administration
- Focus primarily on technical feasibility, but examined estimated costs to compare with alternatives
- Emphasis on “off-the shelf”, commercial technology and hardware
- Revision 1.0 issued Sept 30, 2009

Hydrogen Hub Concept



Ammonia Can Be Cheaper Than Diesel

Price per ton of NH₃ at the end of April for each year

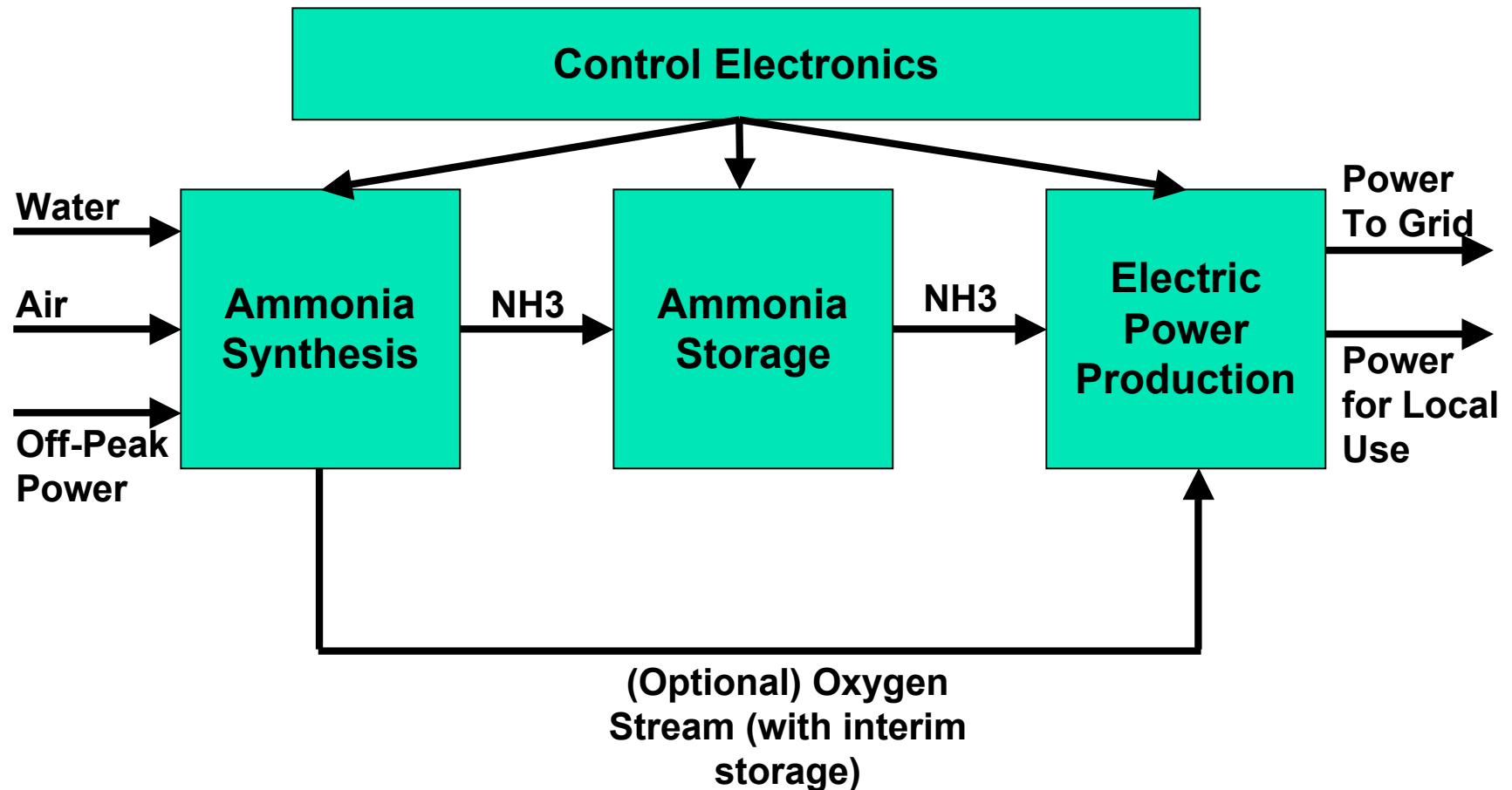


Types of H2Hubs – Two Extremes

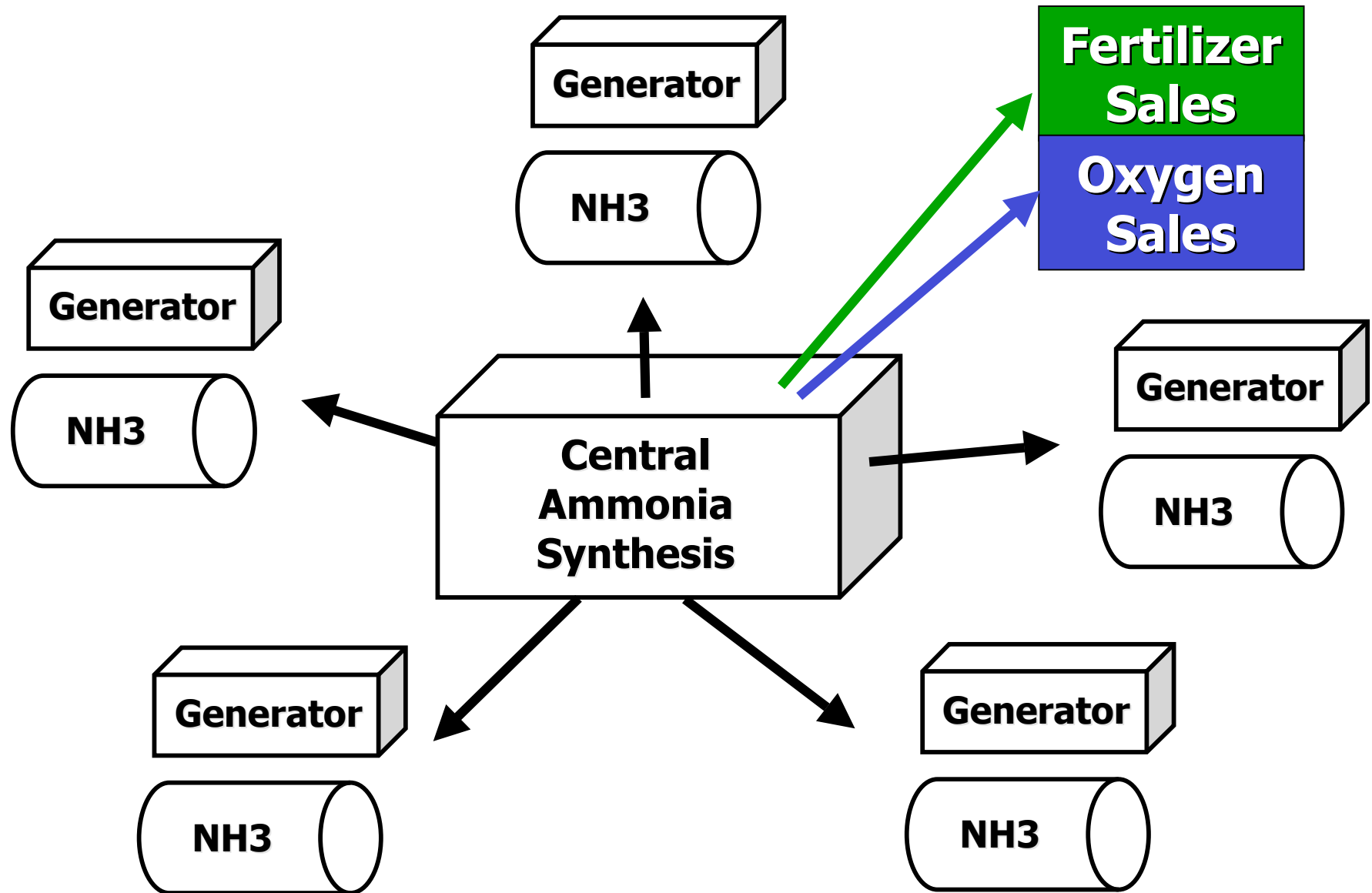
- **Aggregated (On-site NH₃ synthesis)**
 - NH₃ synthesis/storage runs that part of year when electric power is not generate
 - Generally, a “capacity” resource
 - Some NH₃ and O₂ sales to offset costs
 - By-product O₂ stream available to increase generator efficiency
- **Dis-Aggregated (Central NH₃ synthesis)**
 - Year-round NH₃ production
 - Feeds multiple generator hubs; including on-site generation option
 - Surplus NH₃ sold as fertilizer
 - By-product O₂ stream can be sold

Hydrogen Hub Concept

On-Site NH₃ Synthesis Case



Central Synthesis/Satellite Hubs

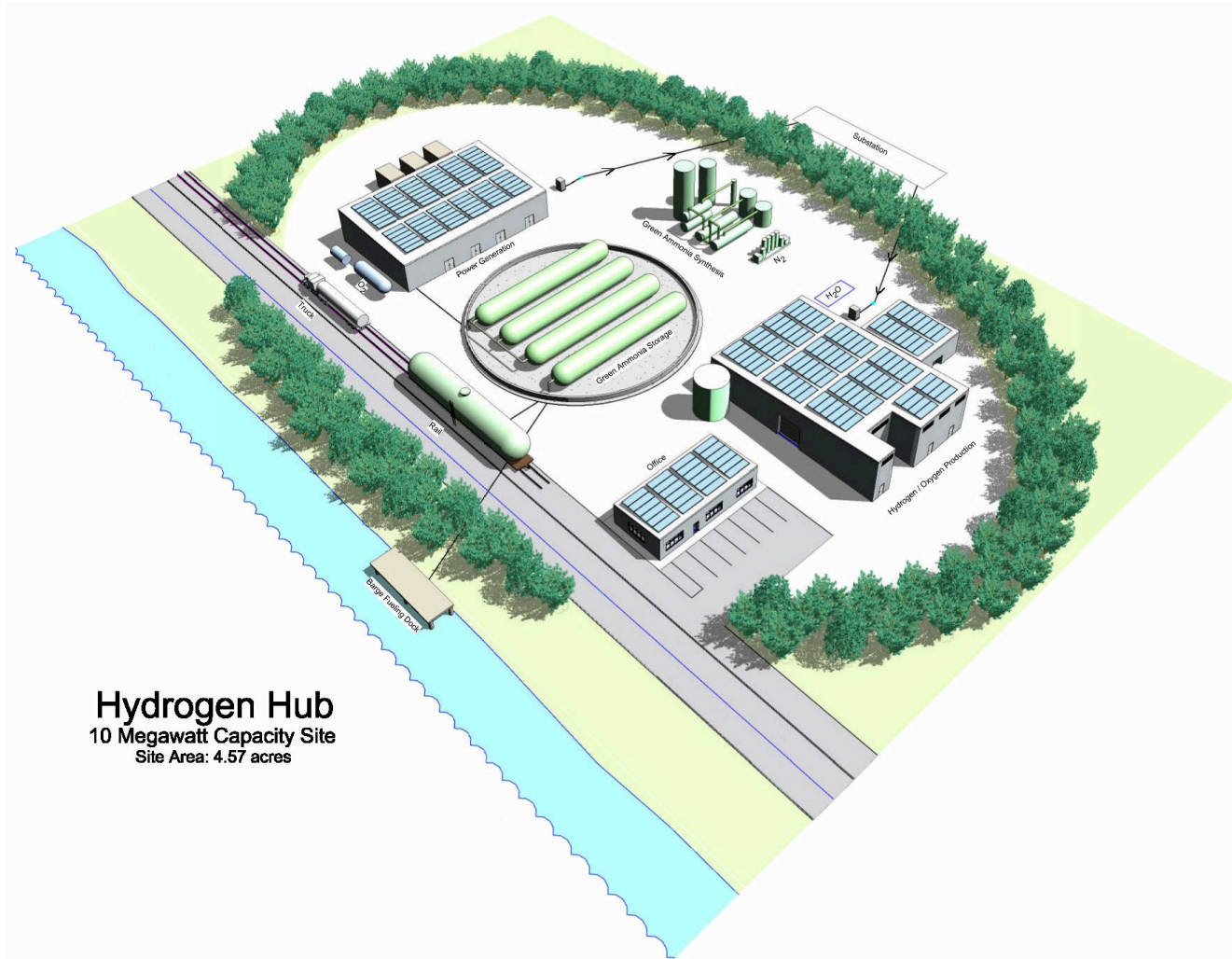


H2Hub Cases Examined

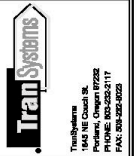
Case	Power Output	Synthesis Capacity	NH3 Storage	NH3 Annual Sales	Estimated Capital Cost
1 – Capacity Resource	10 MW up to 54 hours	10 tpd NH3 (~5 MW input)	260 tons	~3000 tons	\$22 M
2 – Energy Resource	25 MW for up to 16 hours X 6 days X 8 weeks (768 hours)	~30 tpd NH3 (~15 MW input)	9,200 tons	-0-	\$62 M
3 – Agri-Energy	10 MW up to 54 hours	100 tpd NH3 (~50 MW input)	1000 tons agricultural + 260 tons 10 MW capacity	~30,000 tons	\$109 M

Note—All cases assume annual electric rate contract at 3-5 cents Per kWh to keep operating costs and NH3/O2 sales costs competitive

10MW H2Hub Conceptual Design



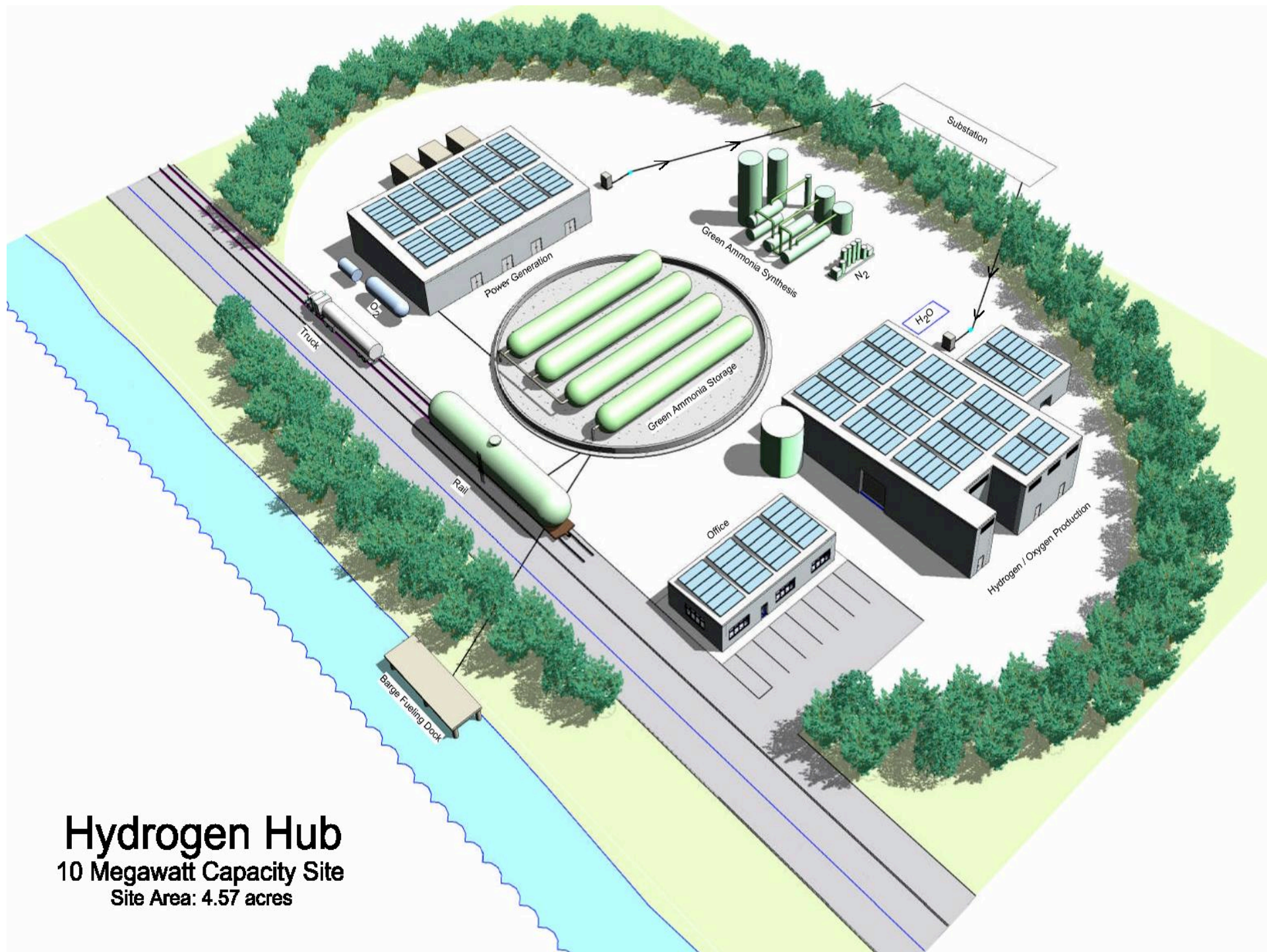
Hydrogen Hub
10 Megawatt Capacity Site
Site Area: 4.57 acres



NORTHWEST HYDROGEN ALLIANCE

REVISIONS	DATE	DESCRIPTION

PROJECT NO: P007000000
SCALE: 1" = 80'-0"
DATE:
DESIGNED BY:
DRAWN BY: DRL
CHECKED BY:
SHEET TITLE:
**HYDROGEN HUB
10 MEGAWATT
CAPACITY SITE**
SHEET NO.
A-102



Hydrogen Hub
10 Megawatt Capacity Site
Site Area: 4.57 acres

Hardware Choices (Current and Developmental)

- NH₃ Synthesis
 - Electrolyzer + Haber-Bosch
 - Solid State Ammonia Synthesis
- NH₃ Storage
 - Standard ~250 psi pressure tanks
 - “Super-safe” tanks
 - Large atmospheric tanks
- NH₃ GenSets
 - Converted diesel (95% NH₃)
 - Spark ignited
 - Combustion turbine
 - Advanced, high-efficiency designs

Preliminary H2Hub Conclusions

- Lots of energy can be stored compactly as NH₃
- Converted diesel gensets are a likely initial choice for H2Hubs
- H2Hubs can be programmed to provide power benefits such as power on demand or synthesis load on/off
- Cases 1 (peaking capacity) and 3 (agri-energy) appear initially to be economically viable, but need further study
- Case 1 capital costs appear to be competitive with major competitors, such as gas turbine peakers
- Role and economics of by-product sales, primarily O₂, need to be studied further
- A carbon-constrained future would align well with H2Hub approach

More Information at ...

- www.HydrogenHub.org
- Includes
 - Draft report / analysis
 - Graphics
 - References / Bibliography

Back-up Slides