NFUEL units for storage of renewable energy

Competitive Decentralized Ammonia Production

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Proton Ventures BV, The Netherlands
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Proton Ventures

- Proton Ventures is based in Schiedam (Netherlands)
Proton Ventures

- Established in 2001
- We are a team of enthusiastic professionals who design and implement customized solutions for our customers.
  - EPC
  - Turnkey solutions
  - and provide investment
- Capable of conducting small to large projects of up to 50 million euros
- We have so far completed around 100 projects
Our NFuel concept

- NFuel concept is based on decentralized production of Ammonia from (decentralized) energy sources to **store** RENEWABLE ENERGY
  - surplus electricity
  - biomass,
  - stranded gas,
  - hydrogen as (by)-product
Our NFUEL concept

• Decentralised production offers
  – Small units, easy to handle for construction
    • No steel construction
    • Fast assembly time at site
    • No big construction effort
  – Multiple, identical units
    • The “Ford”- concept makes units cheap(er) in investment
  – Simple and transportable units, if needed
  – To be realized on small footprint
  – Low or less environmental impact issues
Lightning has tremendous energy content,
However, it cannot be stored and made available when needed.
Energy storage of fluctuating renewables by NFUEL

- Renewable sources are characterised by large fluctuations
  - availability
  - day-night swing
  - maximum-minimum in few seconds
- Creates grid imbalance
  - Leading to energy wastage
  - Curtailing issues,
  - Delayed grid infrastructure
To bridge the energy balance

When production (Upstream) exceeds usage (Downstream), there is a surplus. Conversely, when usage (Downstream) exceeds production (Upstream), there is a shortage.

If not balanced correctly, storage (center) helps to bridge the gap.

Most important thing about Energy is that it should be available when it is needed.
To bridge the energy balance

Most important thing about Energy is that it should be **available** when it is needed.
Customers facing Complications

• Hurdles along the way
  – System misbalance
  – Problem to integrate larger amount of fluctuating power within the system
  – Potential for huge amounts of power wastage
  – Profitability renewables  
    *(depreciation/payback discussions)*
  – Who pays the misbalance
Proton’s Wind Energy Liquefaction – NFuel Unit

Focus 1: Agriculture: NH$_3$ as fertilizer

Production (Upstream)

Surplus of electricity like stranded or curtailed wind
Eg: Curtailed wind

Use Surplus Electricity to Produce a Value Added product, such as Ammonia

Usage (Downstream)

Or Shortage of electricity
Proton’s Wind Energy Liquefaction – NFuel Unit

Focus 2: Industry: Denox in power plants, CO₂ capture, feedstock for chemicals production

Production (Upstream)

Surplus of electricity like stranded or curtailed wind
Eg: Curtailed solar

NFuel Unit

Use Surplus Electricity to Produce a Value Added product, such as Ammonia

Usage (Downstream)

Or Shortage of electricity
Proton’s Wind Energy Liquefaction – NFuel Unit

Focus 3: Transportation fuel: Direct injection in the internal combustion engines, Fuel Cells

Production (Upstream)

Nfuel Unit

Usage (Downstream)

Surplus of electricity like stranded or curtailed wind
Eg: stranded gas

Use Surplus Gas to Produce a Value Added product, such as Ammonia

Or Shortage of electricity
Proton’s Wind Energy Liquefaction – NFuel Unit

Surplus of electricity like stranded or curtailed wind
Eg: by-product hydrogen

Use Surplus hydrogen to Produce a Value Added product, such as Ammonia

General: Energy carrier: easier stored & distributed than power or H2

Or Shortage of electricity

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NFUEL UNIT: Basic Concept

Nitrogen from Air

Ammonia Production skid
$3N_2 + H_2 \rightarrow 2NH_3$

Hydrogen from Water

Renewable Energy Sources
Wind, Solar, biomass, OTEC, Hydropower

Agriculture

Industry

Transports
Simplified PFD NFUEL unit

(*) Cooler plus condensate separator on 3rd stage discharge
(**) Recycle stage with oil filter/separator on discharge if Syngas compressor lubricated
(*** ) Provide pulsation dampeners for both machines to reduce pulsation to about 1 %

Stream number of Material Balance

Proton Ventures BV
date 12-12-2010
NFUEL UNIT 3-D REPRESENTATION®
NFUEL UNIT: key features

• Fully automated process, design & control logic based on safe operation
• Zero Carbon process
• Safe and Proven technology
• Patented electrolysers
• Decentralised operations, hence no need for transport and logistics
• Long technical life
• Recognized international partners for supply of equipment
• Units are skid based, hence easily transportable. Hence, if needed can be relocated in the future if need be.
NFUEL UNIT: key features

NFUEL characteristics:
1,6 MW continuous or about 14 kWh/kg ammonia, excl transport pump(s)
1 m³/hr potable water
app 5000 ft²
110 NM³/hr air
no operational manpower
some maintenance (2-3%)
fully automated
intrinsic safe +

120 kg/hr NFUEL = app 3,3 Mton/day = app app 1000 t/annum
NFUEL UNIT: key features

NFUEL characteristics: Power2ammonia

2 * 125 Nm/hr electrolysers at 4.7 KWh/Nm3 H2
1 Dm-water unit (RO plus)
1 N2 generator (85 NM/3hr N2 pure)
1 syngas compressor
1 recycle compressor
1 ammonia reactor + loop ancillaries
1 storage tank app 15 Mton
1 control system (controlled from NL)
1 power contract
1 off take agreement for ammonia
1 land rental agreement
1 permit
1 license agreement
1 year time (production time)

120 kg/hr NFUEL = app 3.3 Mton/day = app app 1000 t/annum
NFUEL UNIT: key features

NFUEL characteristics: Gas2ammonia

1 mini-ATR for 250 NM3/hr H2
1 Dm-water unit (RO plus) bigger sized than for power
1 N2 generator (85 NM/3hr N2 pure)
1 syngas compressor
1 recycle compressor
1 ammonia reactor + loop ancillaries
1 storage tank app 15 Mton
1 control system (controlled from NL)

1 gas contract
1 off take agreement for ammonia
1 land rental agreement
1 permit
1 license agreement
1 year time (production time)

120 kg/hr NFUEL = app 3.3 Mton/day = app app 1000 t/annum
How does it compare with Gasoline

### Oil Prices ($/gallon vs. $/mmbtu Oil)

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### Ammonia Prices ($/Ton vs. $/Mmbtu Ammonia)

<table>
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<th>$/Mmbtu Ammonia</th>
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Current Gas Prices in Iowa

Decentralized ammonia production – NH3 price between 600-700$/Ton
Crude Oil Price Projection

- World Oil Price Forecast in three cases (adjusted as per 2007 $ prices)
- Data source – DOE (2009)
Oil Price Forecast

- Based on IEA Forecasts (2009 Annual Report)
- Blue line is the Reference case scenario and Red line is the high price scenario
Oil Price Forecast

- Based on IEA Forecasts (2009 Annual Report)
- Blue line is the Reference case scenario and Red line is the high price scenario
Price-point mbtu comparison

- **Price-point comparison of gasoline vs decentralized ammonia production**
- **Here the green line represent the mean of reference and high case scenario of gasoline prices**

![Graph showing comparison with decentralized ammonia production from electricity]
Price-point mbtu comparison

- Price-point comparison of gasoline vs decentralized ammonia production

Expected to be 20-30% cheaper in next 4/5 years
Avenues of capital cost reduction

• Building multiple units at the same time
  – Discounts on equipments from suppliers
• Technological improvements
  – Efficient and cheaper electrolysers
  – Reuse wasted heat (be careful with integrations!)
• Smart construction
  – Eliminate compressors, etc...
• Using by-product oxygen
• Continuous creativity to reduce prices
  – Improving the process and product
Opportunities

• We offer mini-ammonia units for stranded locations
  – To begin with the ammonia can be used as a fertilizer, as this is the established market
  – Over time as ammonia engines develop, farmers can use ammonia as a fuel
  – We are in talks with few partners to develop ammonia engines and generator sets to complete total supply chain.

• Advantages of decentralized fuel production fits the bill of a transportation fuel
  – Multiple points of production scattered around, but at strategic location, which will act as fuel stations for the future
  – Reduced costs and time for handling and transportation of fuel
Why decentralized

- Renewables available at stranded locations offers best opportunities today
  - Trade off with fossil fuels (gasoline costs much higher than average in New York/ heavily concentrated central)
  - Make use of local infrastructure for ammonia
  - Less transportation costs to bring ammonia to stranded area
  - New applications for ammonia in progress
    - Ammonia fuel cells
    - Ammonia power generators
    - Ammonia gas turbines
    - Ammonia Engines (stationary and mobile)
Why decentralized

• Large units have some negatives
  – More re-transportation
  – Storage and logistics problems rise
  – Need for long term, multi client agreements for financing
  – But larger units should be cheaper when more than 6 NFUEL units are required, step change

• 1000 ton/annum unit fits small communities

• 1000 ton/annum units can be easily increased by duplication

• Also important: Be independent! Full control once fuel applications start developing

• Also political reasons: what to do with stranded wind
Conclusions

• NFUEL units available today at 1000 t/annum units
  – power2ammonia and gas2ammonia
  – Proven technology
  – Financing possibilities with banks today

• Other sizes possible today as well, but not as skids

• Capital costs reductions underway
Conclusions

• For ammonia as a fuel
  – Decentralized ammonia production can be already competitive with gasoline at price-point mbtu at stranded locations
  – More area’s will become competitive when gasoline price rise in time
  – Slow introduction is most logical process
  – Small capital investments seem the trend to go
Conclusions

• Ammonia as a fertilizer
  – Present ammonia farmer pricing competitive with NFUEL investment
    • Based on curtailed energy
    • Power balancing
    • To become independent
  – New add-on technology for farmers could make decentralised nitrates as well (patent pending)
Conclusions

• Ammonia as a chemical
  – Green chemicals from NFUEL will be new development
  – NFUEL units may have a positive effect on operating permits
  – Decentralised, high quality ammonia is available without transport and logistics problems
  – At site production of ammonia at power plants for DENOX
Thank you

For more details about our NFUEL- units please email us at info@protonventures.com