



Ammonia



The other Hydrogen???

Hans Vrijenhoef

Proton Ventures, Netherlands

Member of the Ammonia Fuel Network Association

*LCES, Dalian China (October 2011)*



[www.protonventures.com](http://www.protonventures.com)



# Why Ammonia?

K.I.S.S

NH<sub>3</sub>: 50% more hydrogen

Abundantly available raw materials

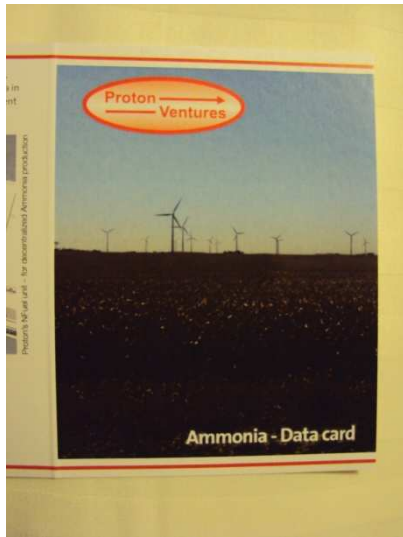
N – Nitrogen from air 78% of earth's atmosphere

H – Hydrogen from water most abundant element  
in the universe

Power: from any sustainable source

**NH<sub>3</sub> – best choice for a  
practical, sustainable alternative fuel**





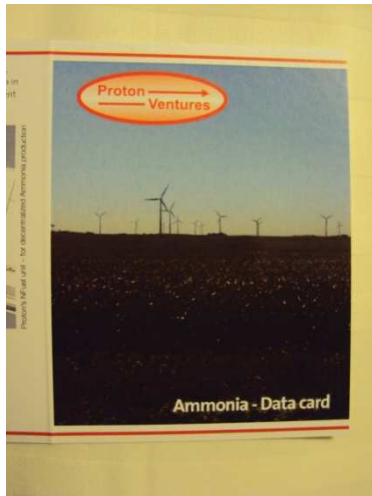
# Characteristics Ammonia

## Important Data:

- Top 3 world chemicals by tonnage
- 99%+ produced with natural gas or coal
- Prevents millions of deaths from hunger
- U.S. uses 15-20 million tons per year
- Needed for corn, wheat, potatoes...
- Many non-agricultural uses
- But:
- One of top GHG producers in world (each ton of natgas NH3 produces 1.8 tons of CO2)

**So, time for change.....**

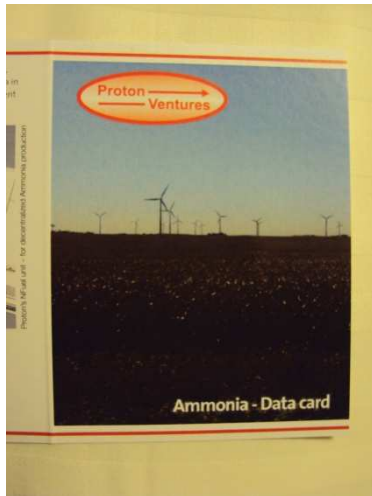




# Characteristics Ammonia

## New Data:

- Ammonia is a Fuel .....as well
- It contains no Carbon
- It is relatively safe to handle ( years experiences)
- It is easy to store ( in Mid-West USA, every village has storage)
- Easy to transport
- Technology for storage in large scale exists today
- People acquainted to use ammonia for fertilisation
- Not so much used for fuel
- Materials comparable to LPG ( Pressure Temp, no Cu)
- LPG tanks can be replaced by NFUEL tanks ( NH3-tanks)
- But:  
**NFUEL shall be produced from sustainable sources**



# Characteristics Ammonia

## New Data:

- LHV : 18,6 MJ/kg vs 42,8 MJ/kg gasoline
  - About 2,2 times more kg required for same distance
- Nox emission: less than 10 ppm
- Storage pressure: app 7 barg/ design app 30 barg
- Boiling point : -33 C at atmospheric pressure
  
- Approximately 2 times more weight required than diesel
  - But no C-emissions
  - New production ways required
  - New applications required



# Production ways

## Existing Processes:

- **Fossil based**
  - Coal to ammonia ( China)
  - Mainly Natural Gas to Ammonia
  - Nafta to ammonia
  - Waste Hydrogen to Ammonia (Hull/UK)
- **Sustainable sources**
  - Wind
  - Solar
  - Geothermal ( contineous)
  - Ocean Thermal (continuous)
  - Hydropower
  - Biomass



# Production ways

## Existing Technologies:

- Steam reforming plus Haber Bosch
- Electrolysers to Ammonia ( Africa/Norway) plus Haber Bosch
- Waste Hydrogen from acetic acid to ammonia plus Haber Bosch
- No proven other technology commercial since 1915 than **Haber Bosch**
- So, if to be produced today Haber Bosch is proven

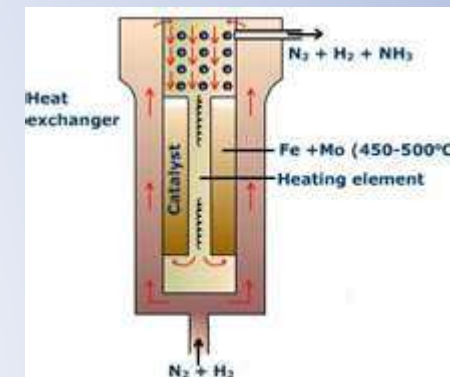


# Production ways

## New Technologies:

- Sustainable source plus Haber Bosch
- Sustainable source plus **SSAS**
- Sustainable source plus **NFUEL (updated Haber Bosch)**
  - Based on wind/solar
  - Based on stranded Gas ( still CO2 emissions)
  - Based on curtailed wind/geothermal/ocean thermal

# Haber Bosch reactor



Typical look of Ammonia plants

# Milestones in NFUEL history

- 1930s Norsk Hydro and Fiat for Cars
- 1940s Belgium—Ammonia Buses
- 1960s U.S. Military “Energy Depot” Study
- 1960s X-15 Rocket Plane
- 1974 Univ Tennessee Ammonia AMC Gremlin
- 1981 “Hydrofuel” Chevy Impala
- 1994 & 1996 Avery and Steele “Ammonia Economy” papers
- 2004 1<sup>st</sup> AFN Conf
- 2007 Matt Simmons receives NH<sub>3</sub> fuel vision
- 2009 NH<sub>3</sub> Hot Rod 9.3L V8
- 2010 First commercial NH<sub>3</sub> engine sold
- 2011 DOE officially recognizes NH<sub>3</sub> as a fuel?

# Stable oil supply?



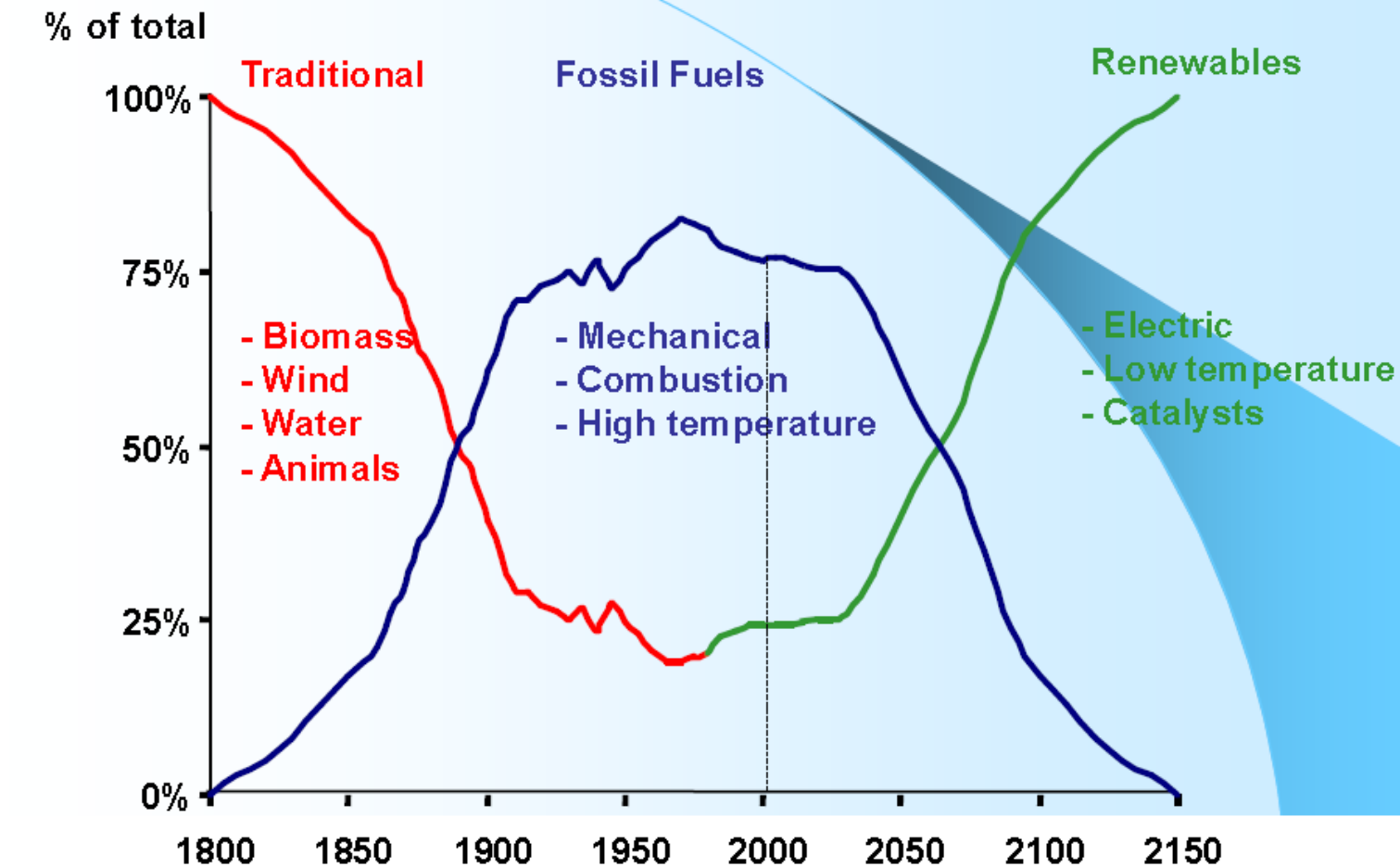
BP Deepwater Horizon 2010  
Source : Norm Olson: Portland conference)

## Is oil as stable as assumed

- Logistics
- Geopolitical problems
- Technical mistakes
- Peakoil
- Economic recession/dip
- Natural disasters
- Terrorism
- Supply/demand balance

# Fossils versus renewables

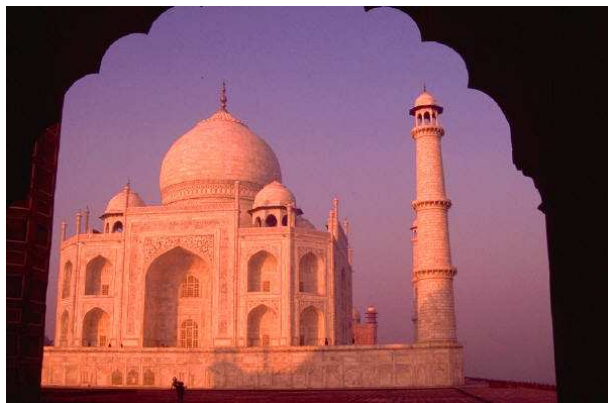
## The Fossil Fuel Era



Source: Ewald Breunese, Shell Netherlands, 14th IAMA Annual World Conference, Montreux, June 14th 2004

# Compounded problem

- Not just finiteness of the oil is a problem, but as large developing economies, such as India and China develop further, the demand for energy will significantly increase in the near future thus putting strain on the global balance between energy supply and demand.

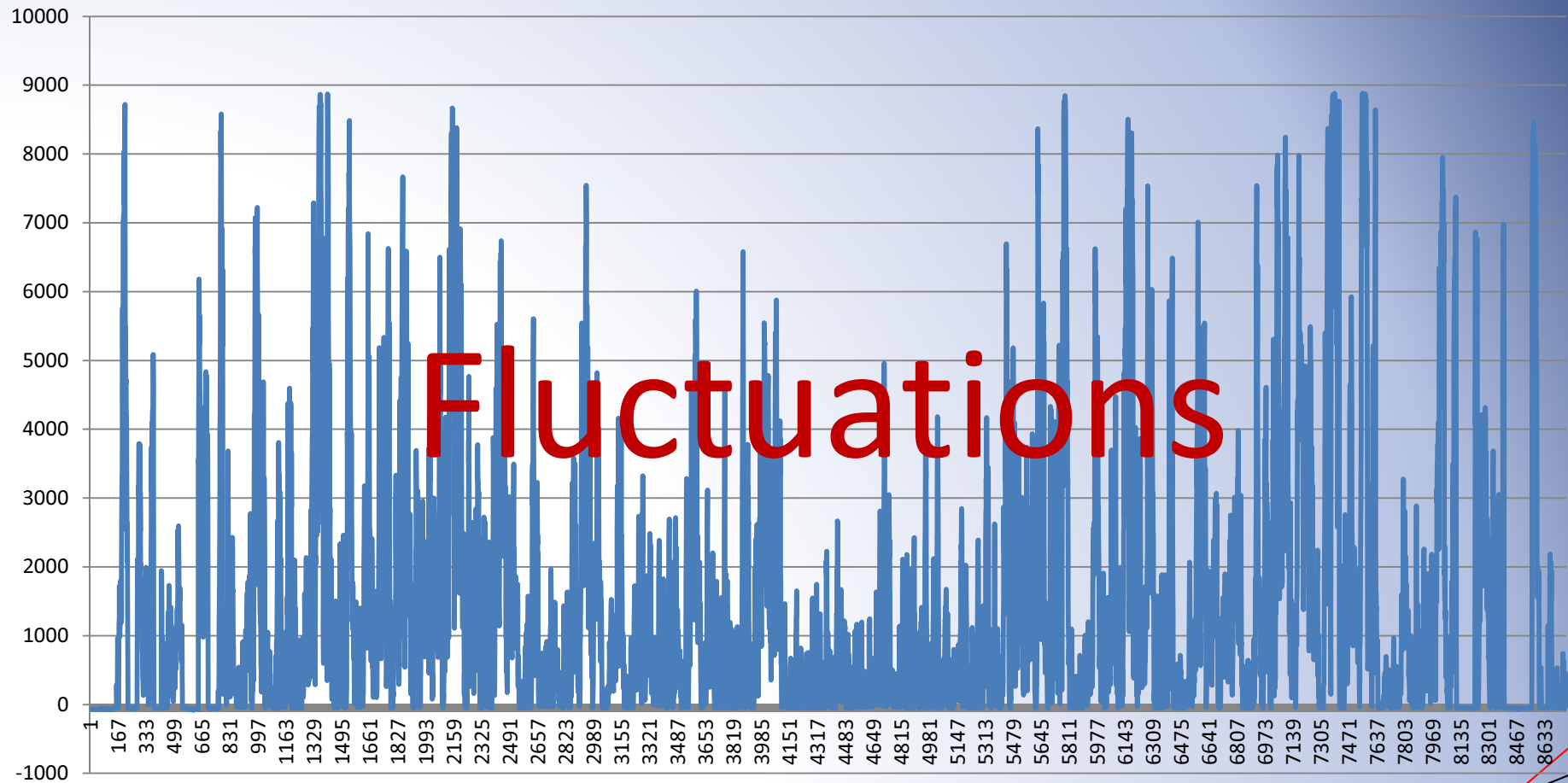


# Benefits of alternative fuels

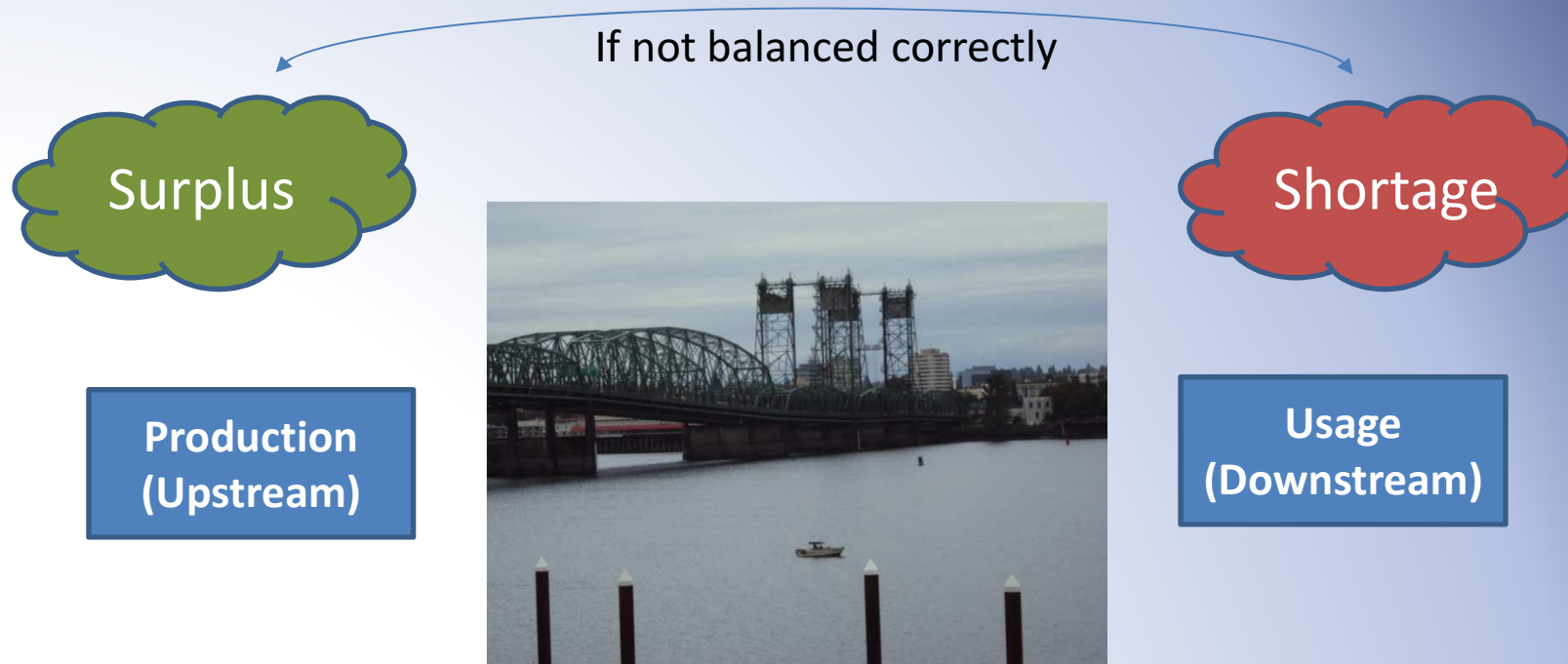
- Benefits include diversification of energy supply, enhanced regional and rural development opportunities, creation of a domestic industry and employment opportunities
- As most of the alternative fuels are distributed more or less evenly over the globe than for example world oil resources, the exploitation of these resources may also increase the security of supply

# Whats holding back Alternative fuels

Hourly



# To bridge the energy balance



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

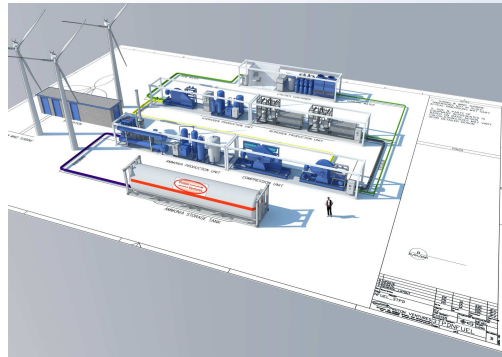
# The Ideal Transportation Fuel

- Can be produced from many sources  
Wind, solar, geothermal, ocean thermal, coal, hydropower, gas
- Offers thus optimisations without changes in cars/trucks/gensets
- Is cost effective
- Environmentally friendly
- Not too bad for health or better than gasoline (Not carcinogenic)
- Could be used in existing vehicles/tanks etc without too much changes
- Proven safety record
- Has enough storage potential over the year
- Logistics for this fuel should be complementary to existing systems \
- Should be produced all over the world ( not in specific “OPEC”-countries)

# Basic NFUEL characteristics

- Has sufficient storage and distribution systems already in place
- Can be produced from various sources all over the world, including stranded locations
- When using NFUEL as fuel
  - Less Nox emission than with fossil fuels ( incl catalysts)
  - NH<sub>3</sub> used as DeNO<sub>x</sub>-agent in SCR-technology
- Few machines did work with ammonia
  - Brussels, XR-99, Chevi-Nh<sub>3</sub> project, engines. Studies ( Louvain Laneuve 2011)

# NFUEL process



H2 via electrolyse  
H2 via reforming  
All decentralised

Fertilisers  
Urea replacer

Green Chemicals  
Denox

NFUEL applications  
Gasturbine  
Direct injections engines



# Today's applications

- Use of curtailed wind to ammonia
  - Upper Mid-west for fertiliser use
  - Green chemicals
  - Denox at stranded locations
- Use of associated gas in oil drilling applications
  - Reduction of flare gas and added value
  - Less pollution at oil wells
  - Use ammonia in fertilisers
- Critical locations for ammonia logistics in large scale
  - City centres
  - Denox plants vs urea or aqua ammonia logistics and power costs
  - Use as Green chemical/lower risks in transport
- Fuel, by cracking ammonia to H<sub>2</sub> and apply in SOFC
- LPG replacement in cars in e.g. NL



# Future applications

- Ammonia for direct NH<sub>3</sub>-fuel cells
  - In development in TUDelft, USA
- Ammonia at stranded locations to produce Ammonia from Wind
  - Convert to power when no wind is available
  - Use ammonia as the battery ( chemical i.s.o. electrochemical battery)
- Use in gensets/ gasturbines for stationary applications
- Use in Diesel and Gasoline vehicles, mainly trucks
  - Supported by Clinton Initiative
  - Comply with euro 5 norms in Europa in specific cities





# Conclusions

NH<sub>3</sub> from coal and natural gas now ( 140 MT/annum)

- NH<sub>3</sub> for Fuel could be
  - NH<sub>3</sub> from renewables and even nuclear ( if accepted) in the near future (Including wind, solar, geothermal, Ocean Thermal and hydropower
  - NH<sub>3</sub> diesel (CI) and spark-ignition (SI) engines now available
  - Direct NH<sub>3</sub> fuel cells in the near future
  - NH<sub>3</sub> is not a poison! It is an very prevalent, naturally occurring chemical. If appears in human bodies
  - Any transportation fuel has associated safety risks but NH<sub>3</sub> is as safe as gasoline and safer than propane according to two, highly-credible studies.
  - NH<sub>3</sub> looks very good now and in the future
  - Hydrogen stored, delivered and utilized in the form of NH<sub>3</sub> is the best choice for sustainable, cost-effective, near-term alternative transportation fuel.

# Proton Ventures

**Proton Ventures innovation centre in  
Schiedam/Rotterdam (Netherlands)**

[www.protonventures.com](http://www.protonventures.com)