AMMONIA,

A RENEWABLE FUEL

WITH ZERO CO_2 EMISSIONS

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0. Summary

The contribution of renewable energy sources to the production of green electricity is well known. The difficulty in *storing* the electricity produced however handicaps them faced with fossil fuels that may be stored in solid or liquid form but with CO_2 emissions.
These fuels could be replaced by green ammonia.

Currently used as fertiliser, ammonia (NH_3) is also a fuel that can be *stored* in liquid form. Its combustion only releases nitrogen and water into the atmosphere, i.e. the only raw materials with electricity that are required for its production.

Its use as a replacement for fossil fuels would allow the planet's energy targets to be met, provided a temporary subsidy is awarded.

1. Background and context of the project

Ammonia (NH_3) is produced through the synthesis of nitrogen (N_2) and hydrogen (H_2):

$$N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

During the first half of the 20th century, *green* NH_3 was produced without any CO_2 emissions from hydroelectricity, water and atmospheric air.

The H_2 came from the electrolysis of water, N_2 in the atmospheric air.

Its *green* characteristic became lost with the gradual replacement of this process by the production of NH_3 from natural gas or coal with CO_2 emissions. The low cost of these raw materials was the main reason for this.

There is currently a revival in interest in the production of *green* NH_3 using more efficient tools and in its use as a fuel or as fertiliser with no CO_2 emissions.

The production of *green* NH_3 at a price competitive with NH_3 from fossil energy sources is the challenge that presents itself.

2. Project objectives

This project is aimed at the production, without CO_2 emissions, of *green* NH_3 from renewable energy sources, water and air, and at its use as fertiliser and storable fuel, also without CO_2, emissions.

3. Detailed description of the project

3.1. Characteristics of ammonia

Ammonia is one of the most widely used chemical products. It is best known as a chemical fertiliser. Nearly 136 million tons were produced worldwide in 2008 [35]. Ships, barges, semi-trailers and pipelines see to its worldwide distribution. A few photos of this are presented in Appendix 4. This network could also distribute ammonia to be used as fuel in competition with hydrocarbons. Its calorific value of 6.25 kWh/kg as opposed to approximately 13.6 kWh/kg for hydrocarbons is compensated by its non-polluting nature. In the same way as propane, it is normally stored in pressurised tanks or - cooled - in high capacity vertical tanks.

Its combustion releases only water and nitrogen into the atmosphere.

Two processes can be used for its production:

- The first using natural gas, water and atmospheric air with CO_2 emissions
- The second using electricity, water and atmospheric air without CO_2 emissions

3.2. Choice of ammonia production process

3.2.1. Preliminary remark

The production of ammonia from *natural gas* takes place *with* CO_2 emissions.

The production of ammonia from *green electricity* produced using renewable energy sources takes place *without* CO_2 emissions.

Green electricity can present itself either to *a network supplied by fossil fuels* or in a *region without a network or with a network supplied by green electricity only.*

- *Network supplied by fossil fuels*

Continuous green electricity could fully replace the fossil fuels until the thermal power plants are shut down. The *stable* and *continuous* flow of these energy sources effectively guarantees the satisfactory supply of the network.

Discontinuous green electricity is however limited to around 20% of network capacity.
Its excessive presence could lead, through its discontinuity, to the shutting down or reduced workload of one or more thermal power plants, at a higher production cost. The recommissioning of a coal-fired plant, should these discontinuous energy sources prove insufficient, would pose serious problems.

Continuous or discontinuous green electricity seems moreover - still in the case of a network supplied by fossil fuels - to be unsuited to the production of NH_3.
The NH_3 produced would only represent *as a fuel* around one quarter of the fossil energy and the CO_2 saved through the direct delivery of green electricity to the network.

- *In a region without a network or with a network supplied by green energy sources only*

Three situations may present themselves:

- The region does not have an electricity network.

  The green energy sources available are used for the production of NH_3, stored in liquid form, for distribution on the world market as *fertiliser*, as *fuel* or for any other chemical application.

- The region has an unsaturated *requester* network supplied by green electricity.

The green energy sources available will supply the network until it is saturated with electricity.

- The region has a saturated *non-requester* network supplied by green electricity.

Any green energy sources still available can be used for the production of NH_3.

Conclusion

As a priority, green electricity will supply the network to reduce CO_2 emissions.
The excess electricity can be used for the production of NH_3.

In the absence of a network, the green electricity can be used for the production of NH_3. This production normally takes place via *continuous* processes.

The preference is thus given to the production of green electricity that is *continuous*, hydraulic, geothermal or plant-based. For this alternative, the ammonia production cost is calculated in 3.4. and 3.5.

In the absence of *continuous* green energy, *discontinuous* green energy such as wind or solar energy should be able to ensure all production during its activity period.
This leads to an oversizing of the facilities and excess costs for the NH_3 produced.
This study does not retain this alternative.

3.2.2. **Production of ammonia from *natural gas*, water and atmospheric air**	3.2.3. **Production of ammonia from *green electricity*, water and atmospheric air**
Ammonia is produced through the synthesis of nitrogen and hydrogen: $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ The hydrogen is obtained via the *reforming* of *methane*, a constituent of natural gas: $CH_4 + 2\ H_2O \rightarrow CO_2 + 4\ H_2$ The nitrogen comes from the atmospheric air. *Disadvantages* Availability of natural gas reserved to certain regions The environmental costs are not - or not sufficiently - taken into account Exhaustible reserves Its cost varies according to its reserves Production of CO_2 CO_2 taxation *Advantage* Hydrogen from NH_3 synthesis is not very expensive	Ammonia is produced through the synthesis of nitrogen and hydrogen: $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ The hydrogen comes from the electrolysis of *water*. The nitrogen comes from the atmospheric air. *Advantages* Universal availability of water Absence of environmental costs Inexhaustible reserves Stability of its cost linked to its abundance No CO_2 production No pollution tax *Disadvantage* The cost of the NH_3 synthesis hydrogen is linked to that of the electricity. The cost of electricity does not *subject to exceptions* allow for hydrogen to be obtained at a retail price competitive with that obtained via methane *reforming*.
Conclusion Financial profitability constitutes the main advantage of the methane reforming process. This however does not take into account the environmental costs caused by the CO_2	Conclusion None of the disadvantages linked to the production of ammonia from natural gas are found with the water electrolysis process. A reduced electricity cost would render the green NH_3 production process via electrolysis competitive.

3.3. Production of green ammonia from electricity

3.3.1. Comparison of electricity production costs

Ammonia is mainly produced using hydrogen from natural gas. A slightly high electricity cost would allow its production using hydrogen from water electrolysis.

Studies [1], [6], [7], [8] and [9] mention the cost of electricity for:

- the most widespread means of production such as coal, gas vapour turbine, nuclear, hydraulic and petroleum,
- the less widespread production means, i.e. green energy sources such as biomass, on-shore wind, off-shore wind, geothermal, photovoltaic and solar reflectors,
- pilot facilities that have not been commercialised such as the concentration solar tower, the energy tower, sea thermal energy and wave energy.

A cost range is given for each of these alternatives. The lowest production costs are selected below, not including pollution. This study aims to determine the conditions allowing for the production of ammonia by electrolysis at a price competitive with the market price.

The internal rate of return of 5% mentioned by the reference study [1] was retained. This rate is not mentioned in the other reference studies.

The classification does not or does not fully include external costs. These are those to be paid as compensation for the pollution caused, damage to health and risks of accidents.

These costs, generally lower for renewable energy sources, are such that this classification can be modified in their favour.

For the establishment of costs in euros, the exchange rate was counted at $1 = €0.684 in 2008.

Table 1: Electricity production cost

Means of production	Classification by diffusion order	Cost of raw materials	% of pro-duc-tion	Lowest costs of kWh	Cost in ascen ding order	Year of refe-rence for costs	Re-fe-ren-ce
Classic means	Coal	$86.34/t	41.0	€0.0201	3rd	2008	[1]
	Gas vapour turbine	$4.78/MMBTU	21.3	€0.0245	6th	2008	[1]
	Nuclear	$110.23/kg ur.	13.5	€0.0198	2nd	2008	[1]
	Hydroelectric	0	15.9	€0.0078	1st	2008	[1]
	Petroleum	$50.37/MWh	5.5	€0.0715	13th	2008	[1]
Renewable energies, less widespread means	Solid biomass	$6.73/MWh		€0.0367	9th	2008	[1]
	Biogas	0		€0.0325	7th	2008	[1]
	On-shore wind	0		€0.0331	8th	2008	[1]
	Off-shore wind	0		€0.0690	12th	2008	[1]
	Geothermal	0		€0.0222	4th	2008	[1]
	Photovoltaic	0		€0.0840	15th	2008	[1]
	Parabolic reflector.	0		€0.0930	16th	2008	[1]
	Tidal power	0		€0.1960	18th	2008	[1]
Renewable energy sources under study	Concentration solar tower	0		€0.0800	14th	2007	[8]
	Solar tower	0		€0.0400	10th	2004	[7]
	Energy tower	0		€0.0235	5th	2001	[6]
	ETM	0		€0.1030	17th	2010	[9]
	Waves	0		€0.1154	11th	2009	[1]

3.3.2. Minimum costs for *continuous* green electricity from *existing* facilities

Only the costs for green electricity from *existing* and *continuous* facilities are retained by this study. *Discontinuous* electricity is not retained as it would have to ensure all production during its activity period and would lead to an excessive cost for the NH_3 produced.

The table below mentions the location, facility capacity, its cost and that of the electricity produced for various sources of *continuous* renewable energy.

Table 2: Characteristics of *continuous* green energies and cost of kWh obtained

Continuous renewable energies	Country	Capacity MW	Facility cost €/kW	Electricity cost €/kWh	Reference
Hydroelectric	China	4,783	613	0.0078	[1]
Geothermal	USA	50	1,198	0.0222	[1]
Biogas	USA	30	1,781	0.0325	[1]
Biomass	USA	80	2,620	0.0367	[1]

3.4. Cost for the production of green NH3, including transport and storage, for FOB delivery

3.4.1. Introduction

The project assesses the cost for the production of NH_3, obtained using hydroelectric energy, geothermal energy, biogas and biomass, including transport and storage up to the sea port, with a view to its FOB delivery on the international market.

The comparison of the FOB price with that of the international market is a measure of the feasibility of the project.

The project objective is to produce green ammonia as fertiliser and fuel, competitive compared to fossil ammonia, for its supply on the international market.

Production capacities of 500 to 1,000 tons a day are current with a clear upward trend.

This study retains a capacity of 1,000 tons of NH_3 a day, for which 180 tons of H_2 a day are required.

The following are presented:

- in 3.4.2. the cost for the production of H_2 and NH_3 from hydraulic energy, geothermal energy, biogas and biomass,
- in 3.4.3. the FOB delivery cost for green NH_3.

3.4.2. Cost for the production of H_2 and NH_3

The detailed calculation of the production cost of H_2 for a unit of capacity 180 t/d is presented in Appendix 1.

That of NH_3 for a unit of capacity1,000 t/d is presented in Appendix 2.

These costs are summarised in the table below for the various energy sources.

Table 3: Cost of H_2 and NH_3

Electricity cost, €/kWh	0.0078 Hydraulic	0.0222 Geothermal	0.0325 Biogas	0.0367 Biomass
Cost for the production of H_2, €/t	**682.3**	**1,410**	**1,929**	**2,141**
Cost for the production of NH_3, €/t	**180.1**	**316.7**	**414.3**	**454.0**

3.4.3. FOB cost of NH_3

The Iowa State University study [18] assesses the cost for the pipeline transport of ammonia over a distance of *1,610 km* and its storage for *45 days* at \$34/t and \$32/t respectively, i.e. \$66/t in total or €45/t at an exchange rate of 1\$ for €0.684. This cost added to the costs presented in the previous table gives the FOB price of NH_3.

Table 4: Cost of NH_3 delivered FOB by a facility with capacity of 1,000 t/d

Energy source	Hydraulic	Geotherm.	Biogas	Biomass
FOB cost of NH_3, €/t	**225.1**	**361.7**	**459.3**	**499.0**

3.5. FOB price of fossil NH_3 versus that of green NH_3 used as fertiliser. Subsidy in favour of green NH_3

In 3.4. the FOB cost of green NH_3 was assessed. This cost is compared below to the price of fossil NH_3 currently sold as fertiliser in Europe with a view to assessing the necessary incentive to the production of green NH_3.

FOB price in Europe of NH_3 in January 2011, not including
the CO_2 pollution cost and calculated at a rate of $1 = €0.721; €/t 310 [20]
CO_2 emissions; t/ t.NH_3 1.5
Pollution cost; €/t.CO_2 22.0, i.e. $30/t.$CO_2$
Pollution cost; €/t.NH_3 33
FOB price in Europe in January 2011, including cost of CO_2 pollution; €/t 343

Table 5: Subsidy required for the sale of green NH_3 used as fertiliser

FOB price of green NH_3; €/t	Hydraulic 225.1	Geothermal 361.8	Biogas 459.3	Biomass 499.0
FOB price of fossil NH_3; €/t	343	343	343	343
Subsidy required; €/t	- 117.9	+ 18.76	+ 116.3	+ 156.0

It seems that the price of green NH_3 produced from hydroelectricity and sold as fertiliser can be competitive compared with fossil NH_3. Compensation is necessary for the production of green NH_3 from other energy sources.

3.6. Price of petrol in the United States versus that of green NH_3 used as fuel. Subsidy in favour of green NH_3

This study does not deal with the necessary elimination of the *small quantities* of NOx present, in the event of the imperfect combustion of NH3 in gaseous emissions. These emissions are out of proportion with the *massive emissions* of CO_2 from the combustion of fossil energy sources.

Table 6 assesses the retail price of petrol in the United States in January 2011 per MMBtu, a calorific unit used in the United States.

Table 7 assesses the retail price of green NH_3 used as fuel in January 2011 per MMBtu.

Table 8 compares these two prices with a view to assessing the necessary incentive for the production of green NH_3.

Table 6: Retail price of petrol in the United States in January 2011 [21]

Including taxes and distribution costs, not including CO_2 pollution; $/gal.	3.20
Not including taxes and distribution costs, *not including* CO_2 pollution; $/gal.	2.5
Not including taxes and distribution costs, *including* CO_2 pollution at $30/t.$CO_2$; $/gal.	2.76
Not including taxes and distribution costs, *including* CO_2 pollution at $30/t.$CO_2$; $/MMBtu	23.77
Not including taxes and distribution costs, including CO_2 pollution at $30/t.$CO_2$; €/MMBtu	*17.14*

Table 7: Retail price of green NH_3 in Europe in January 2011

	Hyd. energ.	Geo. energ.	Biog. energ.	Biom. energ.
FOB price of green NH_3; €/t	225.1	361.8	459.3	499.0
FOB price of green NH_3 used as fuel, not including taxes and distribution costs, CO_2 pollution non-existent; €/MMBtu	*12.76*	*20.50*	*26.02*	*28.28*

Table 8: Subsidy required for the sale of green NH_3 used as fuel

FOB price of green NH_3, *not including* taxes and distribution costs, CO_2 pollution non-existent; €/MMBtu	Hydr. 12.76	Geot. 20.50	Biog. 26.02	Biom. 28.28
Retail price of petrol in the US in January2011, *not including* taxes and distribution costs, including CO_2 pollution at \$30/t.CO_2; €/MMBtu	17.14	17.14	17.14	17.14
Margin, i.e. the difference; €/MMBtu	- 4.38	+ 3.36	+ 8.88	+ 11.14
Subsidy required; as a percentage of the price of petrol in the US	- 25.58	+ 19.59	+ 51.82	+ 64.96
Subsidy required; €/t.green NH_3	*- 77.38*	*+59.26*	*+156.76*	*+196.52*

It seems that the price of green NH_3 produced from hydroelectricity and sold as fuel can be competitive in the United States compared with petrol. A compensation is necessary for the production of green NH_3 from other energy sources and sold as fuel.

In this way, green NH_3 from geothermal energy and sold as fuel in the United States will be competitive there for a petrol price increased by 19.59%.

It should be noted that ammonia has already been used in the past as a road and aircraft fuel. A few photos are presented in Appendix 5.

3.7. Cost of solar electricity versus that obtained using a gas vapour turbine powered by green NH_3

The electricity produced by gas vapour turbine (GVT) from fossil energy could also be produced from green NH_3. The cost of electricity produced by such a facility, presented in appendix 3, is close to that of solar electricity. It completes and prolongs the action - limited by its discontinuity - of these sources of energy. The advantage of ammonia is its character of *continu*ous renewable energy.

4. Conclusions

Green NH_3 can benefit from the existing transport and storage facilities. It is destined to become:

- a competitive fertiliser on the international market, without CO_2 emissions for its production
- a competitive fuel compared with petrol, with no CO_2 emissions during its combustion, and no NOx emissions after treatment of the combustion gases
- a competitive *green fuel* for GVT facilities called upon in particular to supplement the intermittent action of wind and solar energy,

- storable *green energy* that can be used as a replacement - without limitation - for coal and fuel consumed by classic thermal power plants. It supplements and prolongs the action of wind and solar energies limited by their discontinuity,

From this we may expect short-, medium- and long-term benefits for the planet and for all States.

In the short term through *a temporary State subsidiary of €100 per ton of green ammonia produced, whether or not it is manufactured there and whether or not it is imported. This subsidy would be an easy incentive to apply for its promotion with a view to reaching the desired objective.* It is preferable to the penalising of CO_2 currently produced, as CO_2 will always remain present in the atmosphere.

In the medium term through *the installation of factories producing green ammonia*. The technologies are available. A few years would be all that would be required for their installation.

In the long term through a *programme for research and development in the area of promising technologies for the reduction of green ammonia production costs*

5. Reasons to promote the project

The project aims to be recognised for:

. the presentation of a fertiliser and a fuel produced and used without any CO_2 emissions,
. the sustainable improvement that it makes to the environment,
. its technical and economic feasibility,
. the diversification provided for energy sources,
. the meeting of the energy targets of the States and of the European Union in particular.

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Appendix 1 - Calculation of the H2 production cost

Synthesis reaction of NH_3: $N_2 + 3\ H_2 = 2\ NH_3$
Output of the synthesis reaction: 98%
Weight ratio H_2/NH_3: 6/34
H_2 required for the production of 1,000 t/d of NH_3; t.H_2: 180

Hydrogen production, t/d: 180
Availability: 0.97 [12]
Lifetime: 30 years, as for the NH_3 production unit

Electricity consumption in kWh/kg: 50.4 [16]
Electricity consumption in kWh/d: 9,072,000
Electricity consumption in kWh/hr: 378,000
Power of the electricity source in MW: 378

Cost of electricity in €/kWh: 0.0078; 0.0222; 0.0325; 0.0367
Cost of the electrolysis facility in €/MW: 500,000 [16]
Cost of the electrolysis facility in millions of euros: 173.460

Annuity over 30 years at an interest rate of 5% in millions of euros: 12.294721
Cost of the annuity per day in euros: 34,726

Annual operating costs in €/kgH_2: 3% of the investment [16]

Water in litres/kgH_2: 10 [14]
Water in m3/d: 1,800
Assessed cost of water in €/m3: 1
Cost of the water in €/d: 1,800

Cost for the production of H_2 in a production facility with capacity of 180t/d

Electricity cost, €/kWh	0.0078 hydraulic	0.0222 geothermal	0.0325 Biogas	0.0367 biomass
Cost of the annuity, €/d	34,726	34,726	34,726	34,726
Electricity cost, €/d	70,761	201,398	294,840	332,942
Operating costs, €/d	15,534	15,534	15,534	15,534
Water, €/d	1,800	1,800	1,800	1,800
Total, €/d	122,822	253,804	347,245	385,348
H_2 cost, €/t	**682.3**	**1,410**	**1,929**	**2,141**

Appendix 2 - Calculation of the NH_3 production cost

The facility includes:

- the air liquefaction N_2 production unit,
- the Haber-Bosch unit for NH_3 synthesis via N_2 and H_2.

Synthesis reaction: $N_2 + 3\ H_2 = 2\ NH_3$

NH_3 production in t/d: 1,000
Availability, %: 90 [18]
Lifetime in years: 30 [18]

H_2 consumption in kg/kgNH_3: 0.180
H_2 consumption per day in t: 180
H2 cost in €/t.H_2: 682.3; 1,410; 1,929; 2,141

Electricity consumption in kWh/kgNH_3: 0.39 [18]
Electricity consumption per day in kWh: 390,000
Cost of electricity in €/kWh: 0.0078; 0.0222; 0.0325; 0.0367

Cost of the facility in millions of euros: 176.19 [18]

Annuity over 30 years at an interest rate of 5% a year in millions of euros: 11.461
Cost of the annuity per day in €/d: 34,890
Annual operating costs in millions of euros per year; 4% of the investment [18]
Operating costs in euros per day: 19,308

Cost of NH_3 production in a facility with capacity of1,000 t/d

Electricity cost, €/kWh	0.0078 Hydraulic	0.0222 Geothermal	0.0325 Biogas	0.0367 biomass
Cost of the annuity, €/d	34,890	34,890	34,890	34,890
H_2 cost, €/d	122,871	253,905	347,384	385,502
Electricity cost, €/d	3,042	8,658	12,675	14,313
Operating costs, €/d	19,308	19,308	19,308	19,308
Total, €/d	180,111	316,762	414,258	454,013
Cost for the production of NH_3, €/t	**180.1**	**316.7**	**414.3**	**454.0**

Appendix 3 – Estimation of the cost for the production of electricity via an NH_3 gas vapour turbine

Hypotheses:
- The characteristics of the ammonia gas vapour turbine facility are the same as for the natural gas facility
- The investment cost is multiplied by a factor of 1.5 to take into account any possible technical modifications

Combustion of ammonia:
- $4\ NH_3 + 3\ O_2 \rightarrow 6\ H_2O + 2\ N_2$
- NCV, kJ/kgNH_3: 18,600
- Consumption in kgNH_3/MWh: 307 (via a modelling of the combined cycle)

Power in MW: 1,350 [1] Load factor: 0.85 [1] Annual production in kWh: 10,052,100,000

Lifetime: 30 [1]
Cost of the facility in €/kW: 1.5 x 399 = 598 [1]
Annuity over 30 years at an interest rate of 5% in millions of euros: 52.56
Investment cost in €/MWh: 5.23

Operating costs in €/MWh: 2.08 [1]

Cost of fuel in €/t NH_3 FOB: 225.11; 361.76; 459.26; 499.01
Cost of fuel in €/MWh: 69.03; 110.94; 140.84; 153.03

Cost for the production of electricity via an ammonia gas vapour turbine

Investment cost in €/MWh	5.23	5.23	5.23	5.23
Operating costs in €/MWh	2.08	2.08	2.08	2.08
Cost of fuel in €/MWh	69.03	110.94	140.84	153.03
Electricity cost in **€/kWh**	**0.076**	**0.118**	**0.148**	**0.160**

Appendix 4 – Photos of existing ammonia storage and transport facilities

Atmospheric storage of ammonia

Atmospheric storage of liquid ammonia, which may vary between 1,000 and 5,000 tons, while awaiting its transport:

Figure 1: Source: http://www.mannvit.com/Industry/AmmoniaStorage/

Transport of ammonia

1. By pipeline, then by boat

Figure 2: Source: http://www.bfpl.com.au/index.php?option=com_content&task=view&id=5&

Transport of ammonia by pipeline to a port with a view to its transport by boat (up to 40,000 tons):

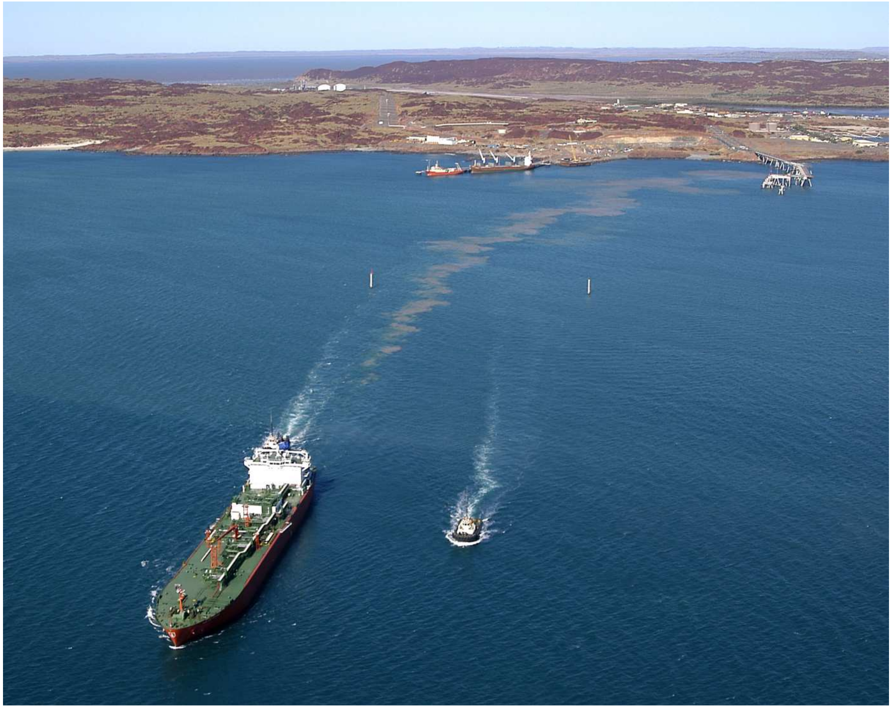

Figure 3: Source: http://www.bfpl.com.au/index.php?option=com_content&task=view&id=5&

The ammonia pipelines and storage terminals in the USA are depicted below:

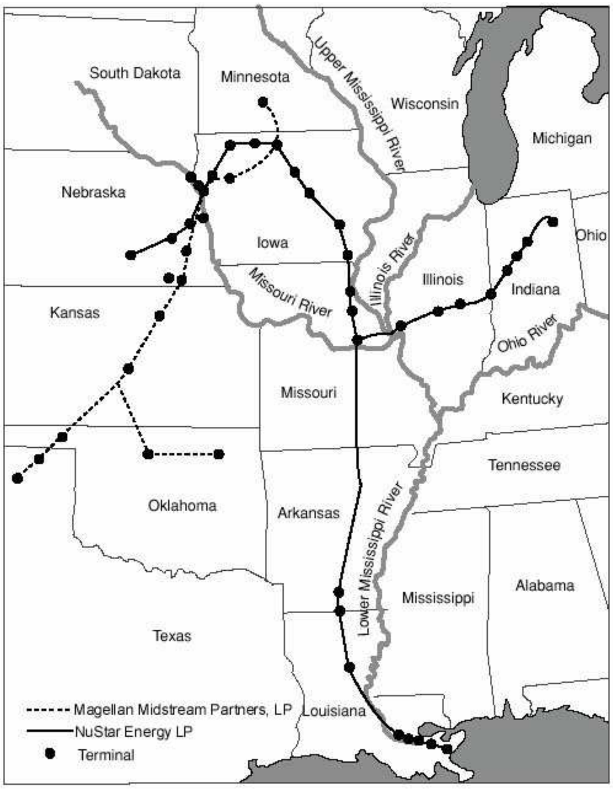

Figure 4: Source: [18]

2. By lorry

Transport of between 7,500 and 57,000 litres of liquid ammonia by lorry, from the port to the place of use of the ammonia:

Figure 5: Source: http://bnhgastanks.com/products-catagories/ammonia-tanks

Appendix 5 – Ammonia used as a road and aircraft fuel

Below is the first vehicle to have travelled using ammonia in Belgium in 1943. It covered several thousand kilometres without any problems.

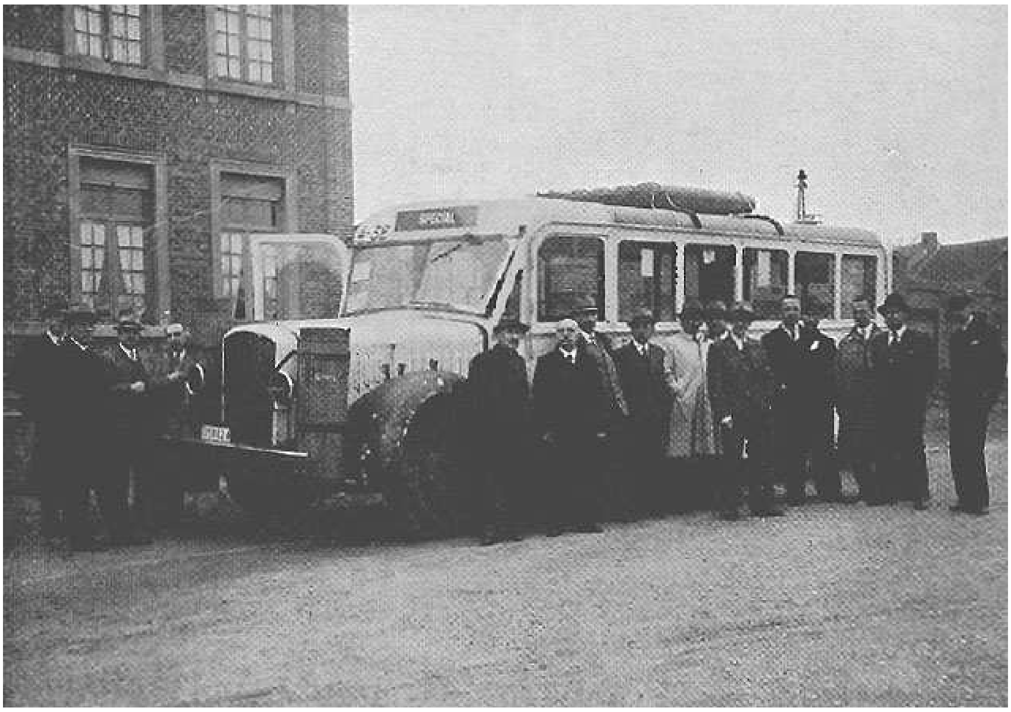

Figure 6: Source: http://www.ammoniafuelnetwork.org/

And here is the *X-15 rocket plane* which flew fuelled by ammonia in the 1960s.

Figure 7: Source: http://www.ammoniafuelnetwork.org/

Appendix 6 - List of abbreviations

- H_2: hydrogen
- NH_3: ammonia
- N_2: nitrogen
- NOx: nitrous oxides
- FOB: free on board, without transport costs and other duties and taxes
- MMBtu: millions of BTU (British Thermal Unit) and 1 BTU=1,054-1,060 J (joules)
- NCV: net calorific value
- kW, MW: kilo- and megawatts, unit of power, 1 W=1 J/s
- kWh, MWh: kilo- and megawatt hour, unit of energy, 1 Wh=3,600 J