Production of competitive green NH3 fuel

Next green NH3 plant: where and when ?
An environmental and economical approach

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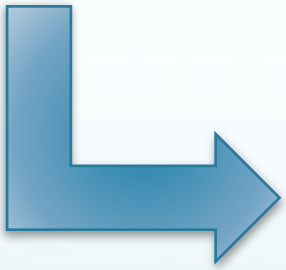
Introduction

- Humanity needs to reduce its **CO2 emissions.**
- There is a need for energy **storage** and **continuous green sources.**
- NH3 has almost all advantages of fossil fuels.
- NH3 already has an infrastructure.
- ➔ Where is the best energy source to produce green NH3

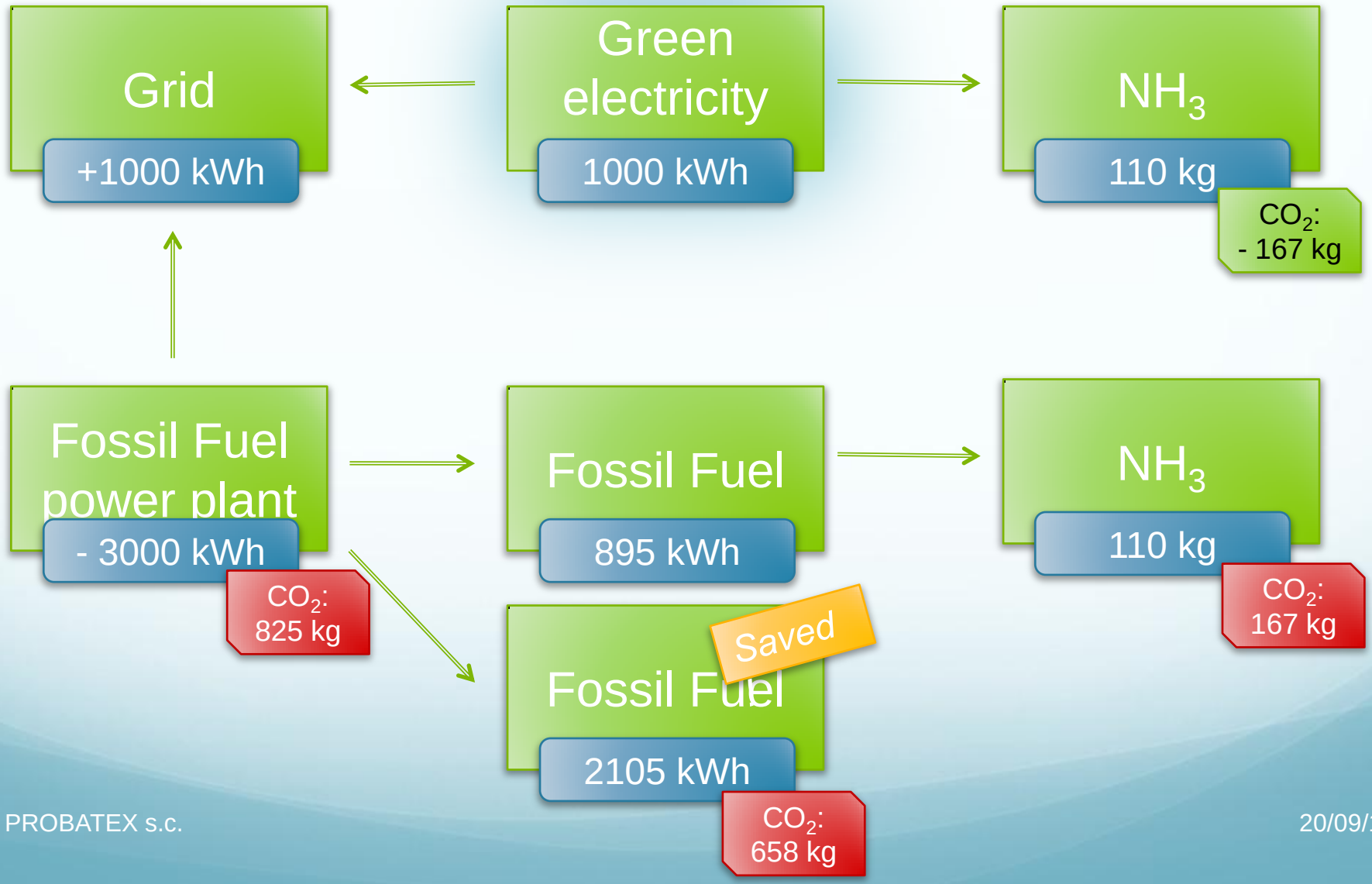
Selection of the green sources

- NH3 or the grid
  - → The best choice
- NH3 production requirements
  - → constraints on the green source

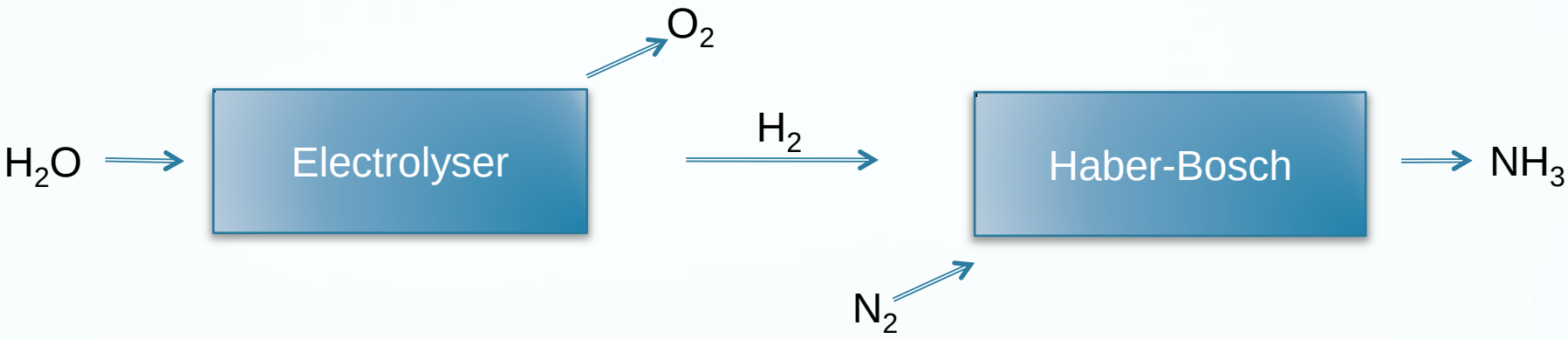


Identification of preferable electricity sources

NH_3 versus the Grid



Green NH_3 production constraints



- The Haber-Bosch process is a chemical process
  - Optimal efficiency is reached at its nominal capacity
  - Efficiency rapidly decreases when going away from its nominal capacity
- ➔A continuous electricity input is requested
- ➔ Deviation to this principle is possible but will always hardly impact the production cost.

Green NH_3 production constraints conclusion

- To get competitive NH_3 the source of electricity shall be continuous,
- A large scale production plant is required.

Sources of electricity

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]

Green sources selection for cost evaluation

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]

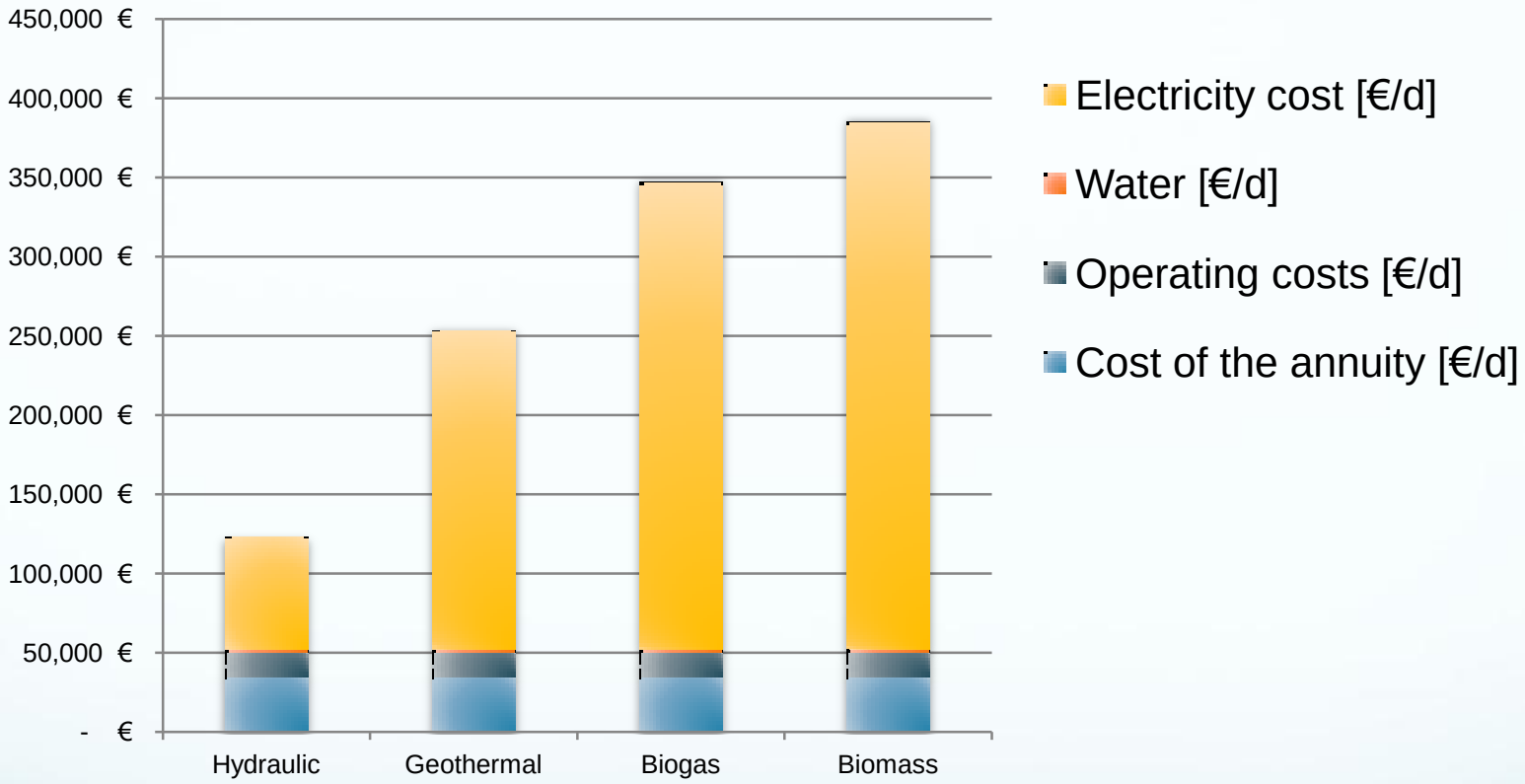
Production cost up to FOB delivery

- Assumptions:
  - Production capacity of **1000** t/day
  - Electrolysis + Haber-Bosch
  - Internal rate of return: 5%
- Computation steps:
  - Production of H_2
  - Production of NH_3
  - Transport and storage

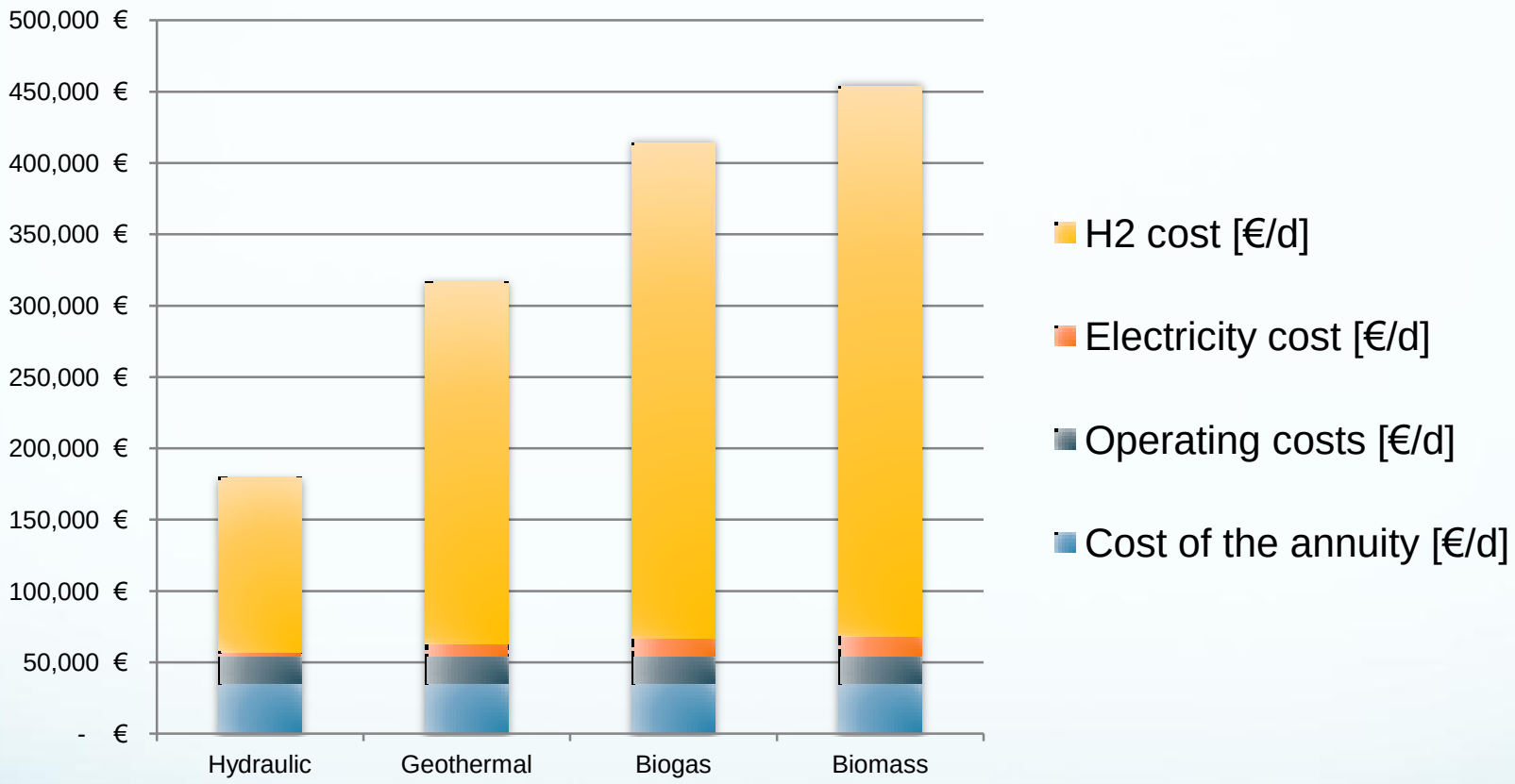
- Results includes cost of:
  - Investment (annuity)
  - Operating and maintenance
  - Water
  - Electricity
  - Transport and storage

  ➔FOB (Free On Board)
- Assessment against
  - NH3 market price,
  - gasoline market price.

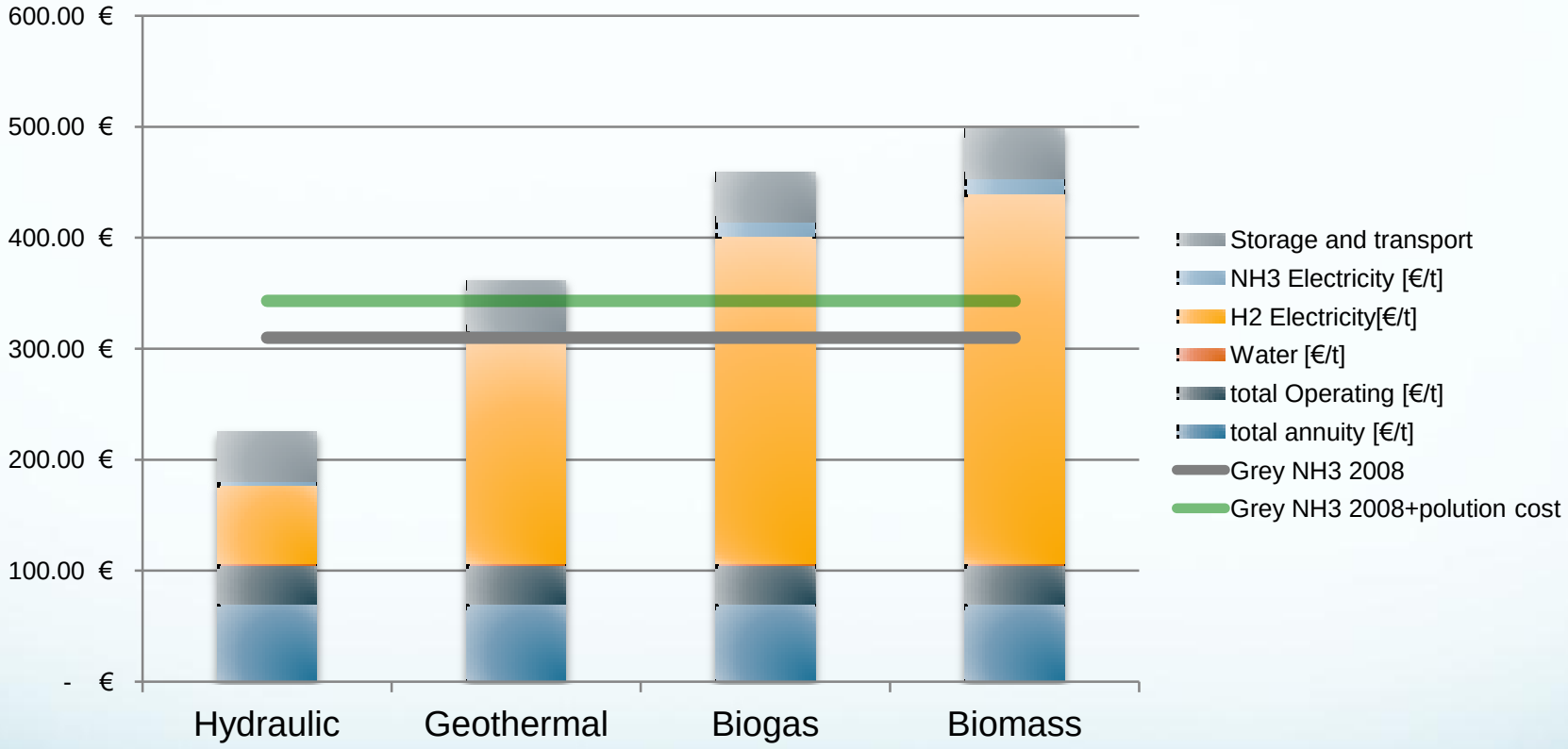
Production cost of 180 t/day of H_2



Production cost 1000 t/day of NH_3



Cost summary and assessment against NH_3 market



-118	19	116	156	Subsidy req. €
-172	27	170	228	Subsidy req. $

Assessment against gasoline

Distribution price $/gal.	**$ 3.20**
Taxes removed $/gal.	**$ 2.5**
including CO2 pollution at $30/t.$CO_2$; $/gal.	**$ 2.76**
including CO2 pollution at $30/t.$CO_2$; $/MMBtu	**$ 23.77**
including CO2 pollution at $30/t.$CO_2$; €/MMBtu	**€ 17.14**

	Hydrolic	**Geothermal**	**Biogas**	**Biomass**
FOB price of green NH_3, €/MMBtu	12.76	20.50	26.02	28.28
Retail price of petrol 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; $/t.green NH_3	-113	87	229	287
Subsidy required; €/t.green NH_3	***-77***	***59***	***157***	***197***

Conclusion

- Where?
  - Use distant renewable energy sources
  - Use continuous sources
- When?
  - Competitiveness on fertilizer, fuel and electricity markets is already a fact for some sources
  - Known technologies exist
  - Green Ammonia is a storable renewable energy
  - ➔ Start Now!
- Lobbying for political involvement into a subsidy policy
  - Enlarge potential sources
  - Kick-off incentive
- Research programs in the area of promising technologies

Thank you for your attention!

The full report is available on http://blog.probatex.be

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