Research Dimensions and Main Pillars in Sustainable Energy

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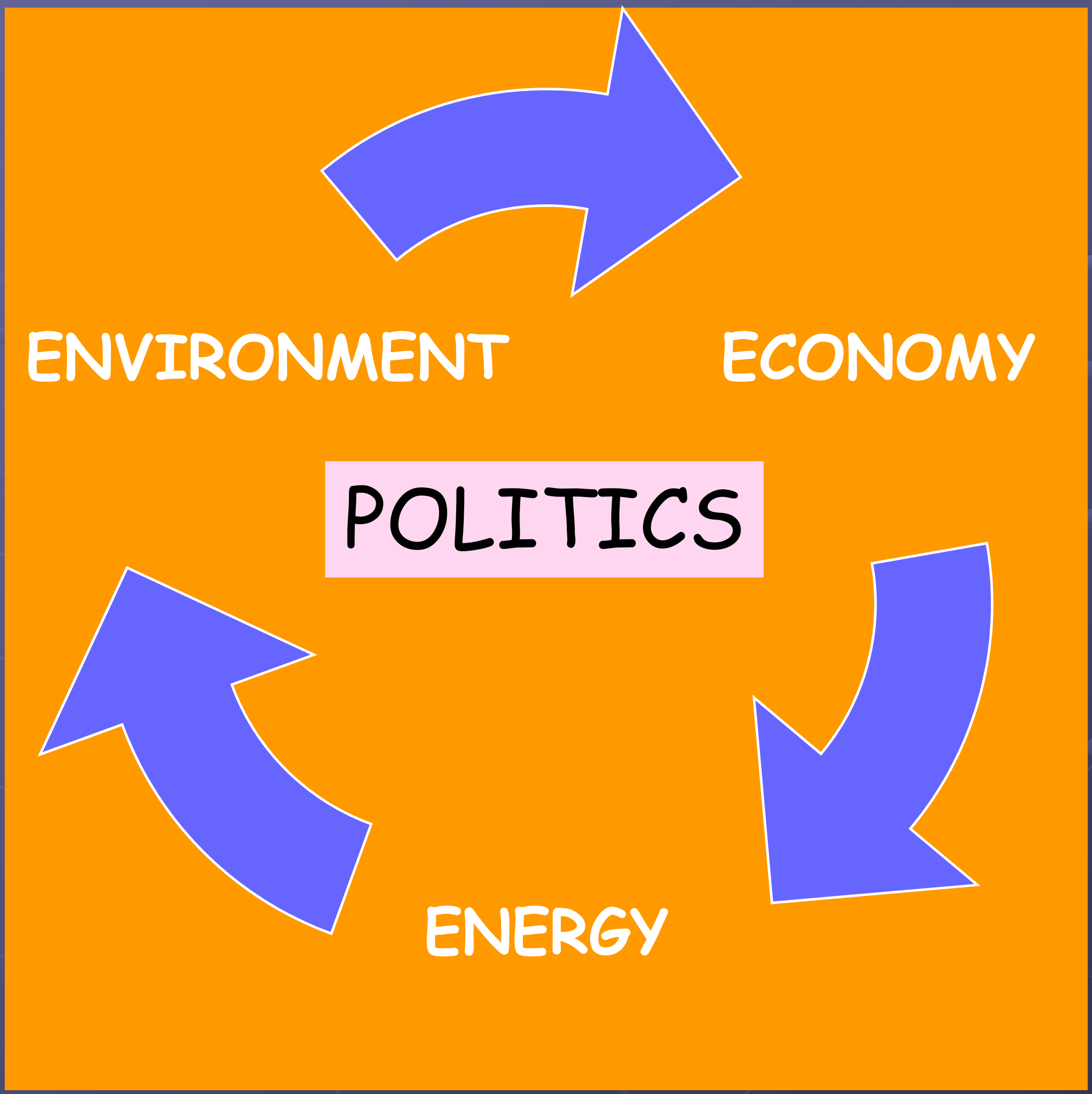
OUTLINE

- Introduction
- Energy Dimensions
- Environmental Dimensions
  - Is it global warming or global warning?
  - Prescription(s) and side effects!
- Sustainability Dimensions
- Main Pillars
- Research Dimensions
- Research Domain
- Potential Solutions
- Conclusions

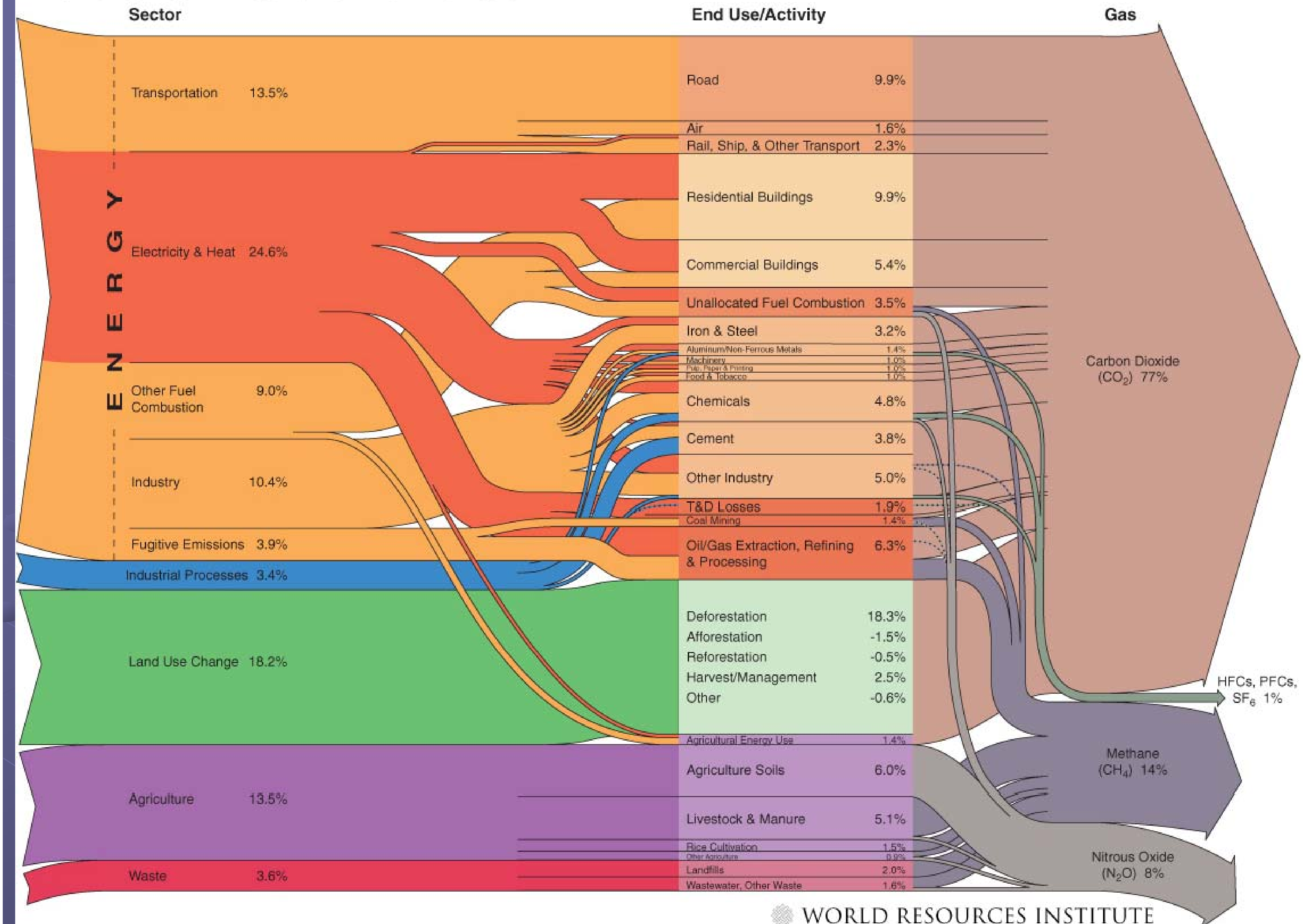
ENERGY DIMENSIONS

- Energy is a key item in our relations with the environment. Energy consumption determines how much and how severely we can affect our environment, and how damaging or healing our interactions with it are.
- Its role is vital for our life and for our economy. Examples are:
  - in homes for lighting, domestic appliances, televisions, computers, etc.;
  - in factories to power the manufacture of the products we use everyday; and
  - in cars, trucks, ships and aeroplanes to transport people and goods.
- Energy issues will shape the future and future policies.

3E + 1P = ?

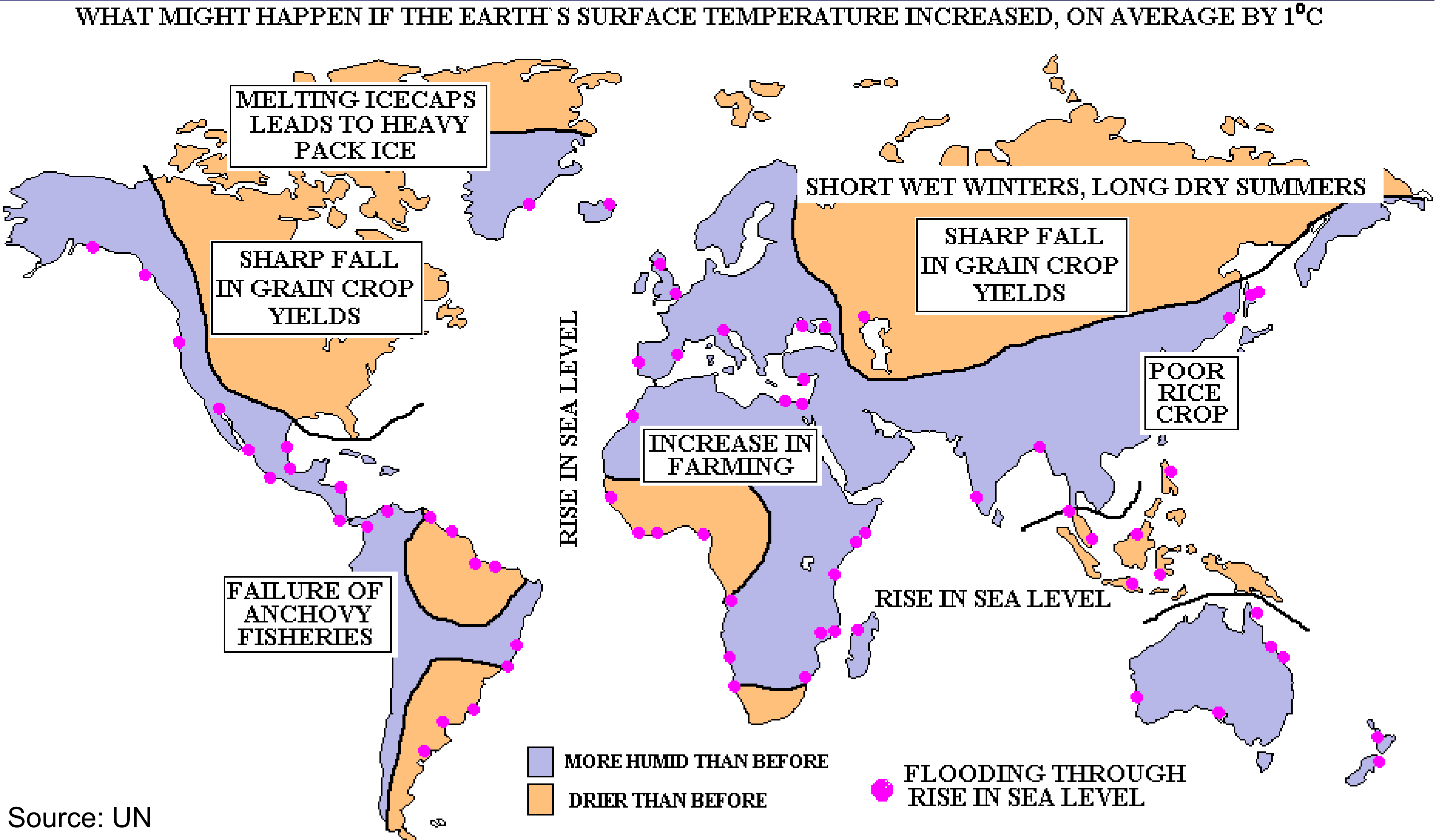


World GHG Emissions Flow Chart



WORLD RESOURCES INSTITUTE

Effects of Global Warming



Source: UN

☠ Some recent catastrophic events: Cyclones in Bangladesh (>10,000 casualties) and Burma (>20,000 casualties)!

Is it global warming or global warning?

http://news.nationalgeographic.com/news/2004/12/photogalleries/global_warming/photo9.html

- Warm temperatures melted an area of western Antarctica that adds up to the size of California in January 2005, scientists report.

1928
South Cascade Glacier, Washington

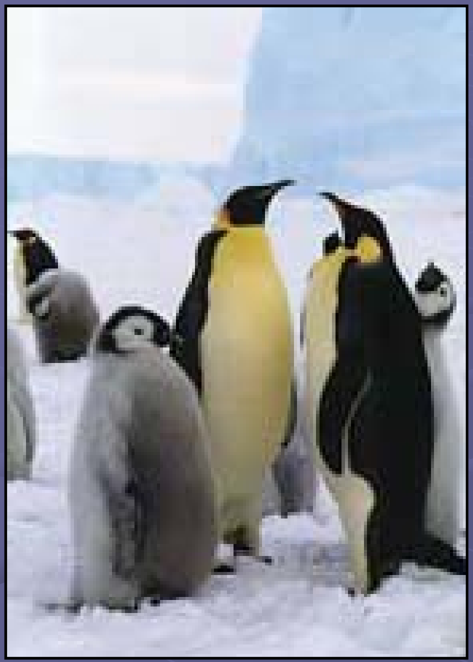
1979
South Cascade Glacier, Washington

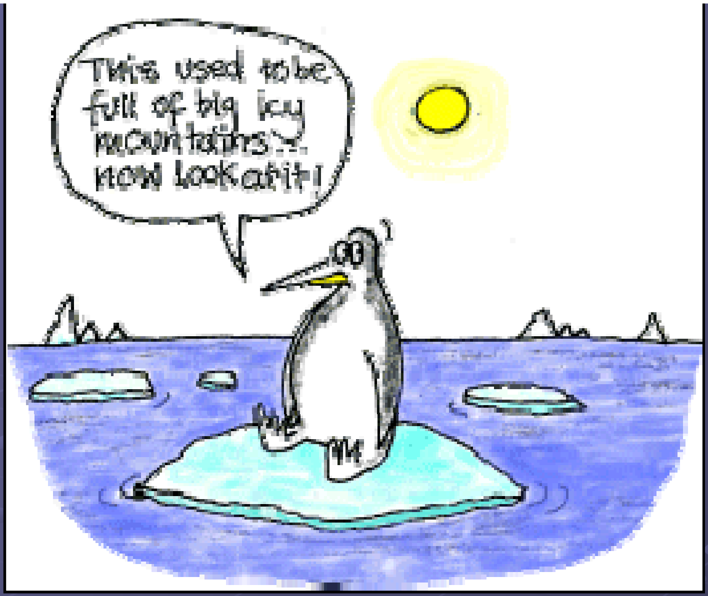
2003
South Cascade Glacier, Washington

F Evidence of melting was found up to 900 km inland from the open ocean, farther than 85° south (about 500 km from the South Pole) and higher than 2 km above sea level.

Now

Before

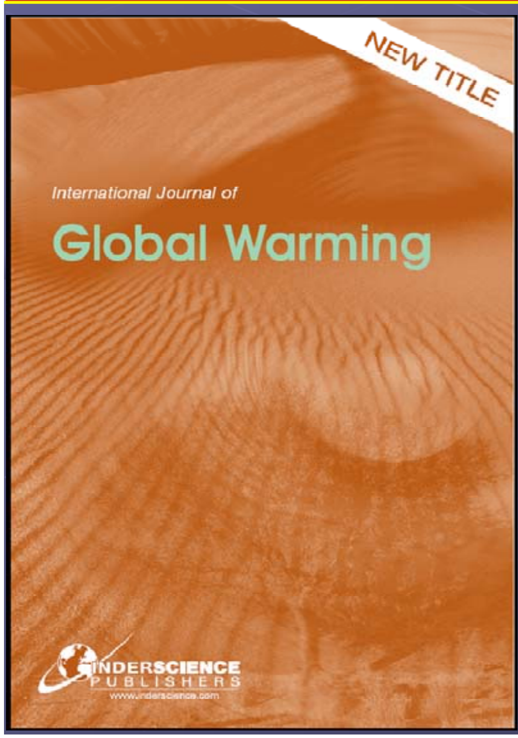




http://tiki.oneworld.net/features/global_warming.html

TO BRING ALL DISCIPLINES TOGETHER FOR LOCAL AND GLOBAL SOLUTIONS

GLOBAL CONFERENCE ON GLOBAL WARMING 2009



5-9 July 2009

Istanbul, Turkey

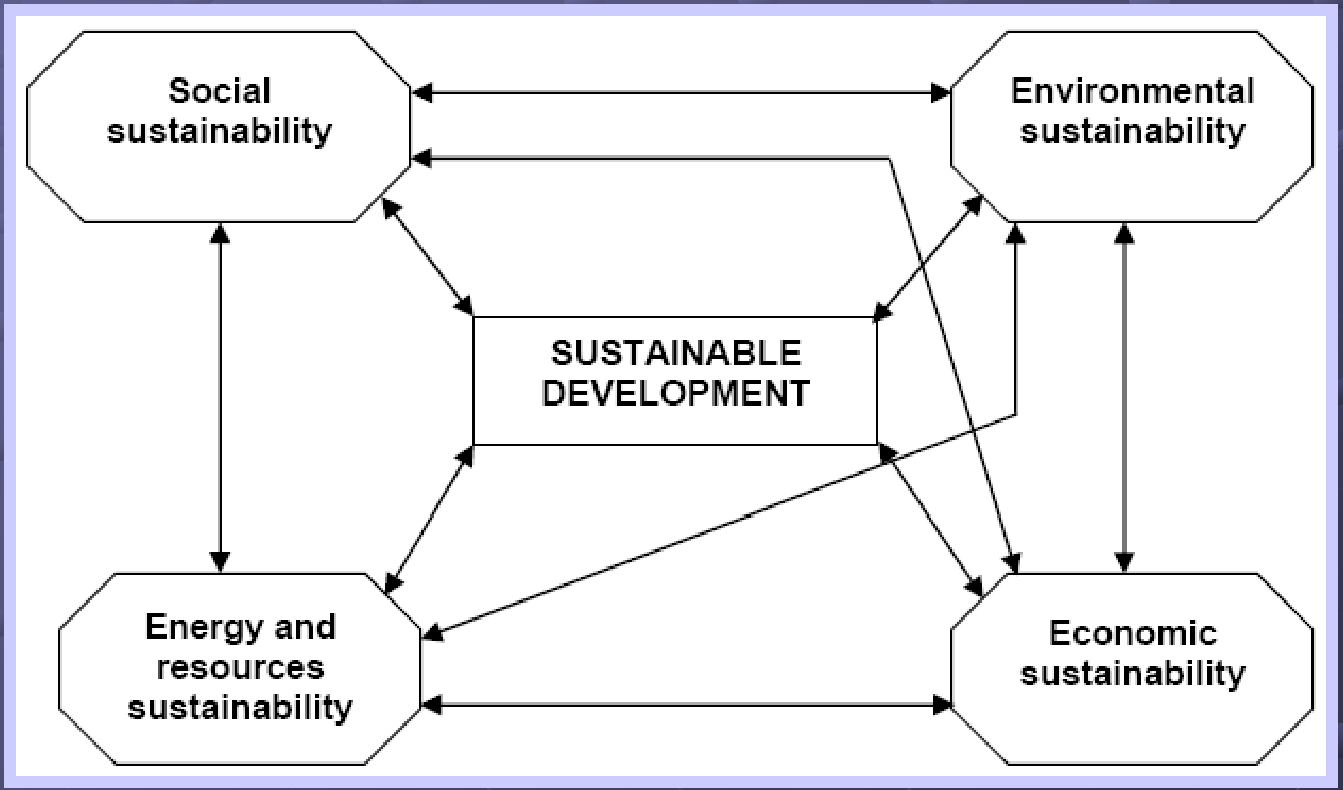
www.gcgw.org

Conference Chair: Ibrahim Dincer

SUSTAINABILITY DIMENSION

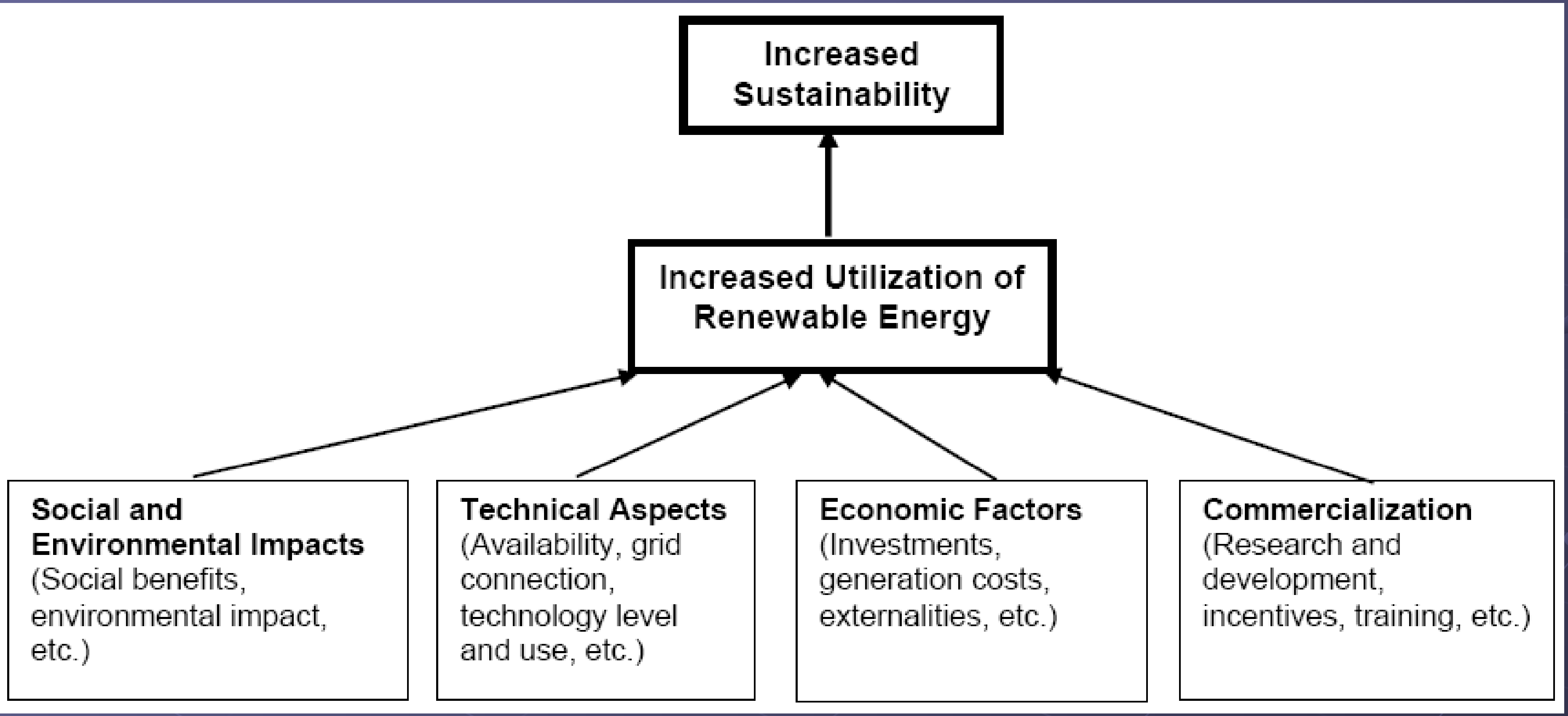
Think, Use, and Live sustainable ⟶ Sustainable future

- → Sustainable development within a society requires a supply of energy resources that, in the long term, is readily and sustainably available at reasonable cost and can be utilized for all required tasks without causing negative societal impacts.
- → It requires that energy resources be used as efficiently as possible.



Factors impacting sustainable development, and their interdependences.

Renewables → Sustainable Development.

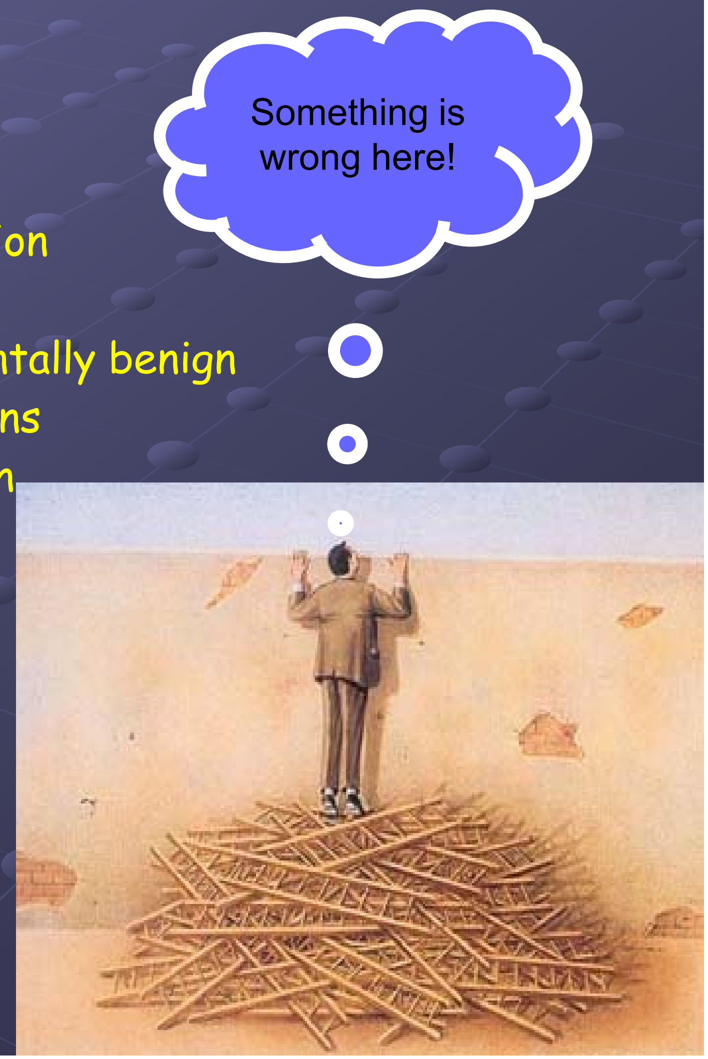


Key Items for Sustainable Energy Systems

- Consistency: Short term actions should be compatible with long-term goals and the viability of the system.
- Renewables: Systems should depend on energy efficient and cost effective renewable sources, and operate using environmentally benign technologies.
- Diversity: Systems should be adaptable for distinct characteristics and capabilities of the components.
- Efficiency: All elements should be analyzed, designed and improved based on the 2nd law analysis (exergy).
- Inclusiveness: All elements should be included in an efficient and effective operation of the system.
- Interdependency: All elements should be well interconnected.

PRESCRIPTION

- Changing lifestyle and habits
- Making systems and applications more effective and efficient
- Using environmentally benign and cleaner technologies
- Using renewable and green energy
- Implementing hydrogen and fuel cell technologies
- Conserving energy
- Diversifying energy options
- Purchasing more efficient appliances
- Giving priority to district energy systems and cogeneration
- Providing proper education and training
- Making energy systems and applications more environmentally benign
- Using more cost effective energy systems and applications
- Seeking alternative energy dimensions for transportation
- Using sustainable fuels
- Increasing public awareness
- Taking necessary energy security measures
- Monitoring and evaluating energy indicators
- Implementing right energy strategies and policies (avoid side effects!)
- etc.



Side effects??

☛ More sustainable FUTURE………

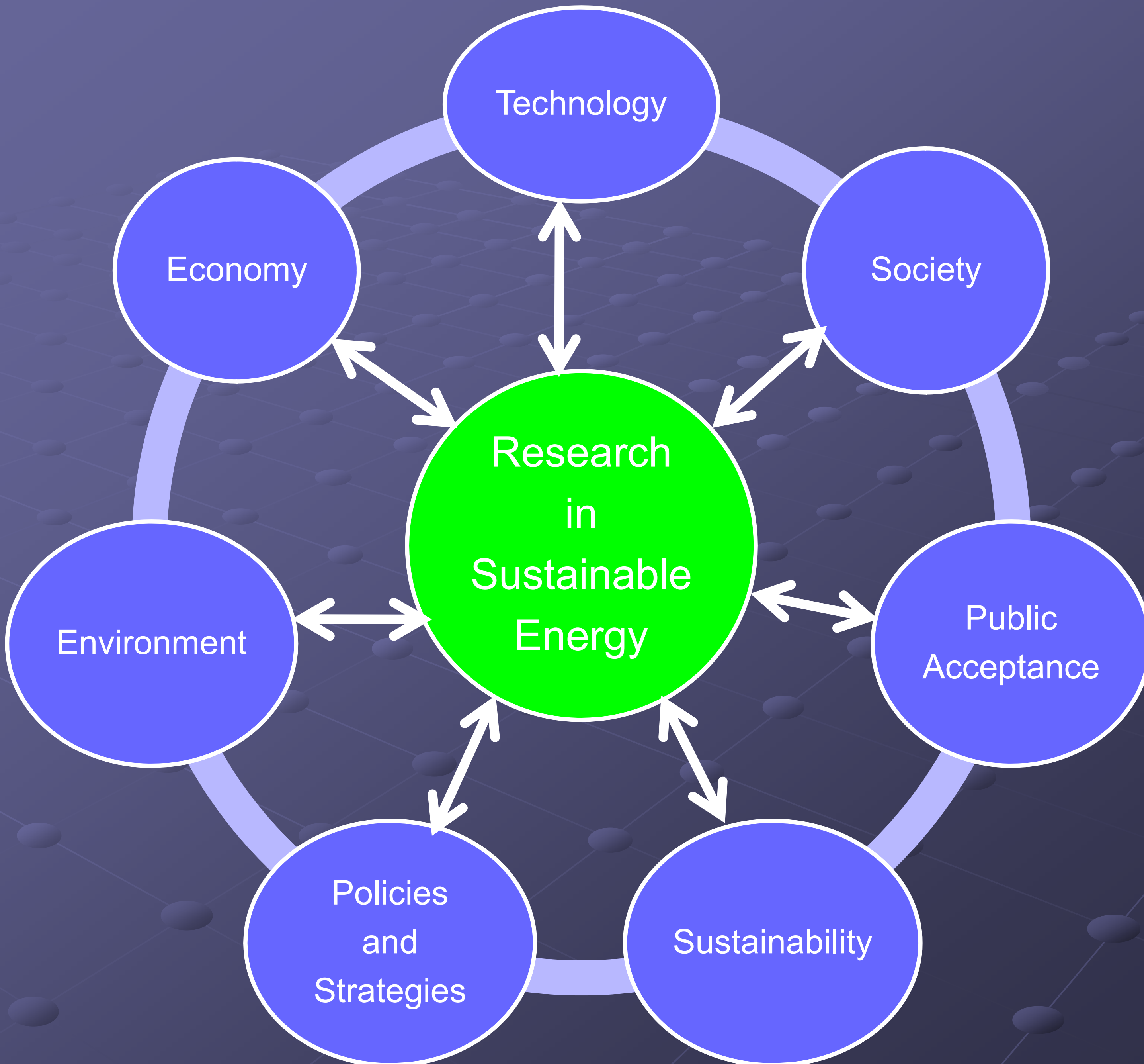
HOW TO CURE THE PROBLEM?

by

by

We need to change our diet!

RESEARCH DIMENSIONS



MAIN PILLARS

- Better efficiency
- Better cost effectiveness
- Better resources use
- Better design and analysis
- Better environment
- Better sustainability
- Better energy security

FEATURED ANALYSIS, November/December 2008

Energy Gauge: Who Exactly Is In Power?

by Christopher King, Editor

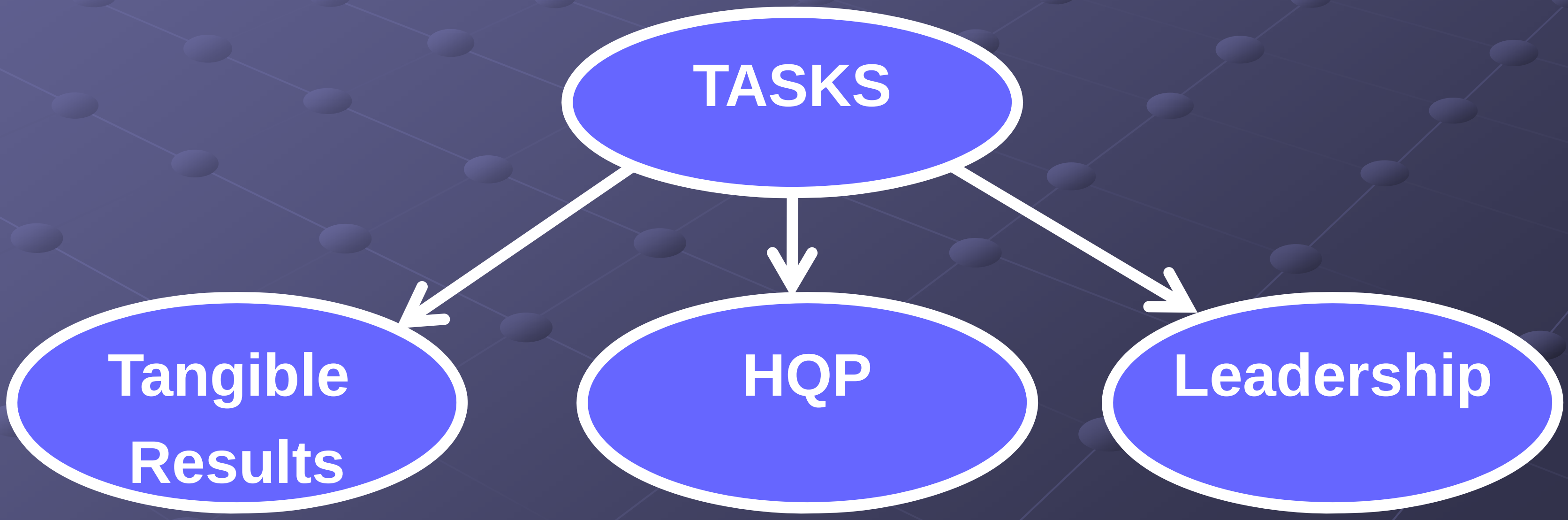
PDF

Highly Cited Authors in Energy & Fuels, 1998-2008
(Ranked by total citations)

Rank	Name	Institution	Concentration	Papers	Citations
1	Ayhan Demirbas	Karadeniz Tech. U., Turkey	Biofuels	245	1,891
2	Rafael Kandiyoti	Imperial College London	Coal Derivatives	111	1,045
3	Rommel Noufi	Natl. Renewable Energy Lab	Solar Cells	17	959
4	Imbrahim Dincer	U. Ontario Inst. Technol.	Fuel Cells	94	910
5	Kim Dam-Johansen	Tech. Univ. Denmark	Combustion	48	877

RESEARCH CHALLENGES

- Always competing against myself:
  - To improve level of my achievement
  - To do better and better by working on new challenges
  - To deliver tangible outcomes
  - To equip/encourage/motivate my HQP to go beyond their limit, and
  - To play a leadership role in the international community



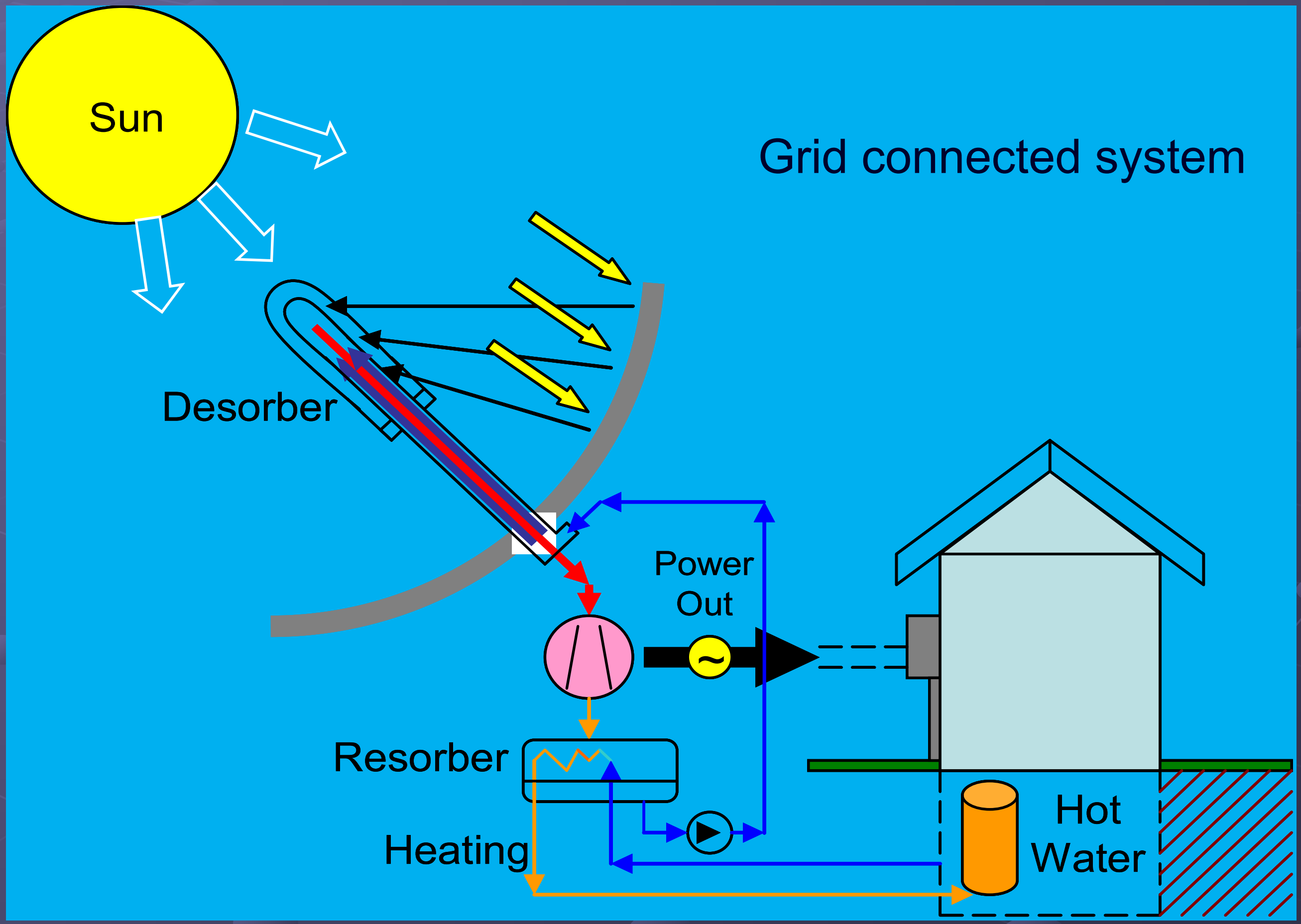
SOME SUSTAINABLE RESEARCH PROJECTS/TOPICS

- Novel solar dish systems for multi-generation purposes
- Ammonia as a sustainable fuel and H_2 source
- Novel wind exergy and solar maps
- Life cycle assessment
- Solar hydrogen systems
- Geothermal based hydrogen systems
- CO_2 capturing from atmosphere and flue gases, and storage
- Biomass-based hydrogen production systems
- Hybrid renewable hydrogen production systems
- Integrated power and FC systems
- New FC designs and configurations for implemntation
- Ammonia fuel cells
- DMFCs for micro and portable devices
- MCFCs for power production
- Rotating reactor type CLC system for zero emissions
- H+ SOFC systems for power production
- Nuclear based hydrogen production
- etc.

Novel Solar Dish Systems for Poly-Generation

Components:

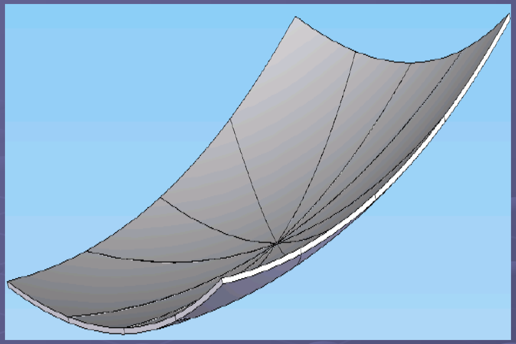
1) Solar collector
   - Solar concentrator
   - Solar receiver
2) Expander
3) Resorber
4) Ammonia-water pump
5) Electrical generator
6) Solar tracking system
7) Inverter
8) Warm water storage



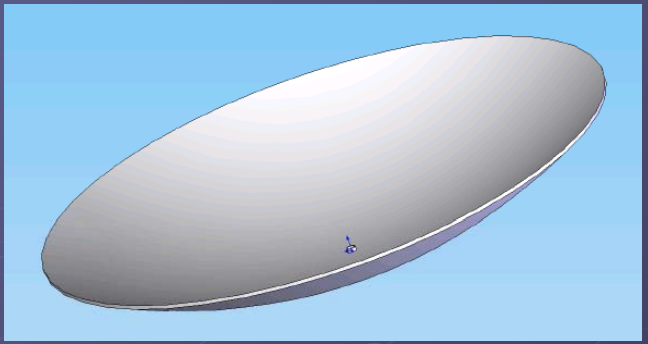
Novel Conceptual Designs

Collector Unit:
- Mirror Dish
- Receiver Unit

Mirror Dish

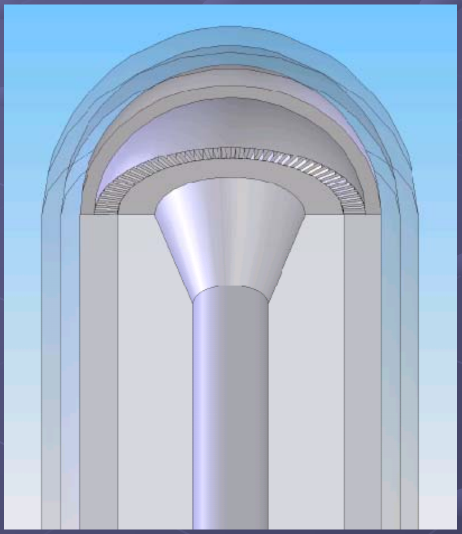


Squared Dish

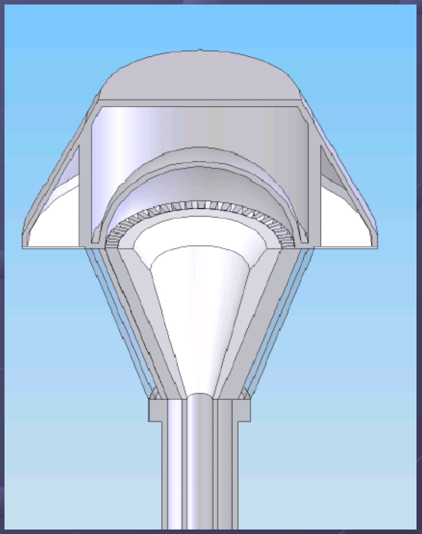


Rounded Dish

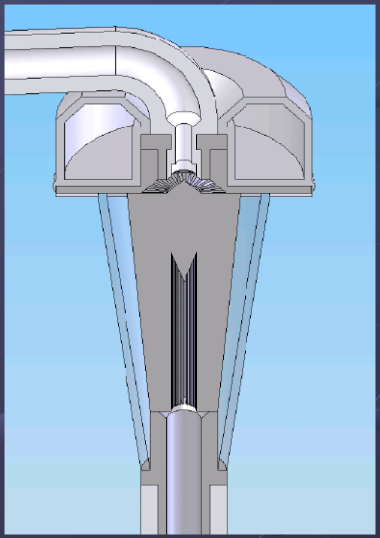
Receiver Unit



Evacuated Tube Receiver (Design 2, Assembly I)



Cone Receiver (Design 3, Assembly II)



Once Through Receiver (Design 4, Assembly III)

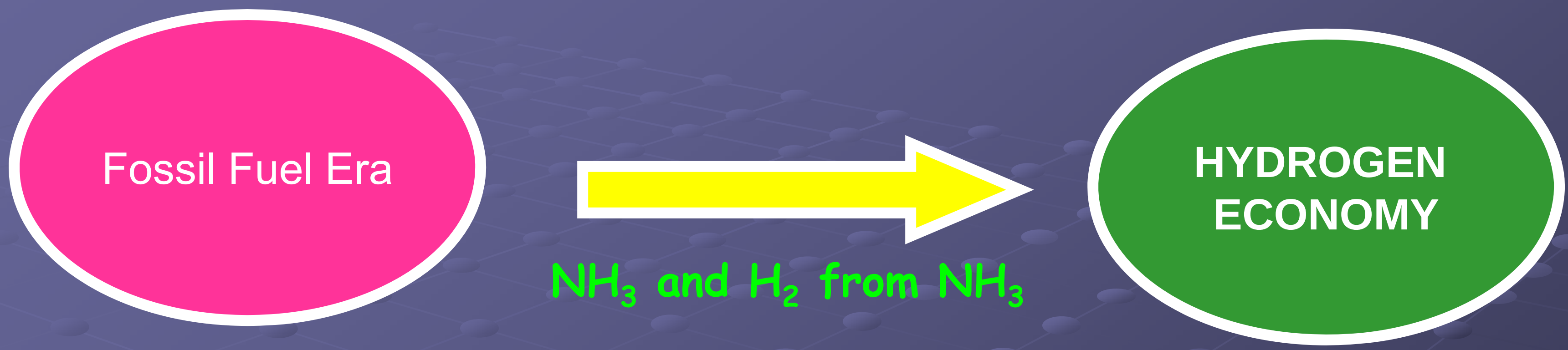
Novelties to be Patented

- Solar receivers
  - Cone receiver
  - Cavity receiver
  - Nozzle receiver
  - Evacuated tube type cylindrical receiver

- Heat engine: Using ammonia-water and scroll or screw expander and system regulation through ammonia concentration adjustment

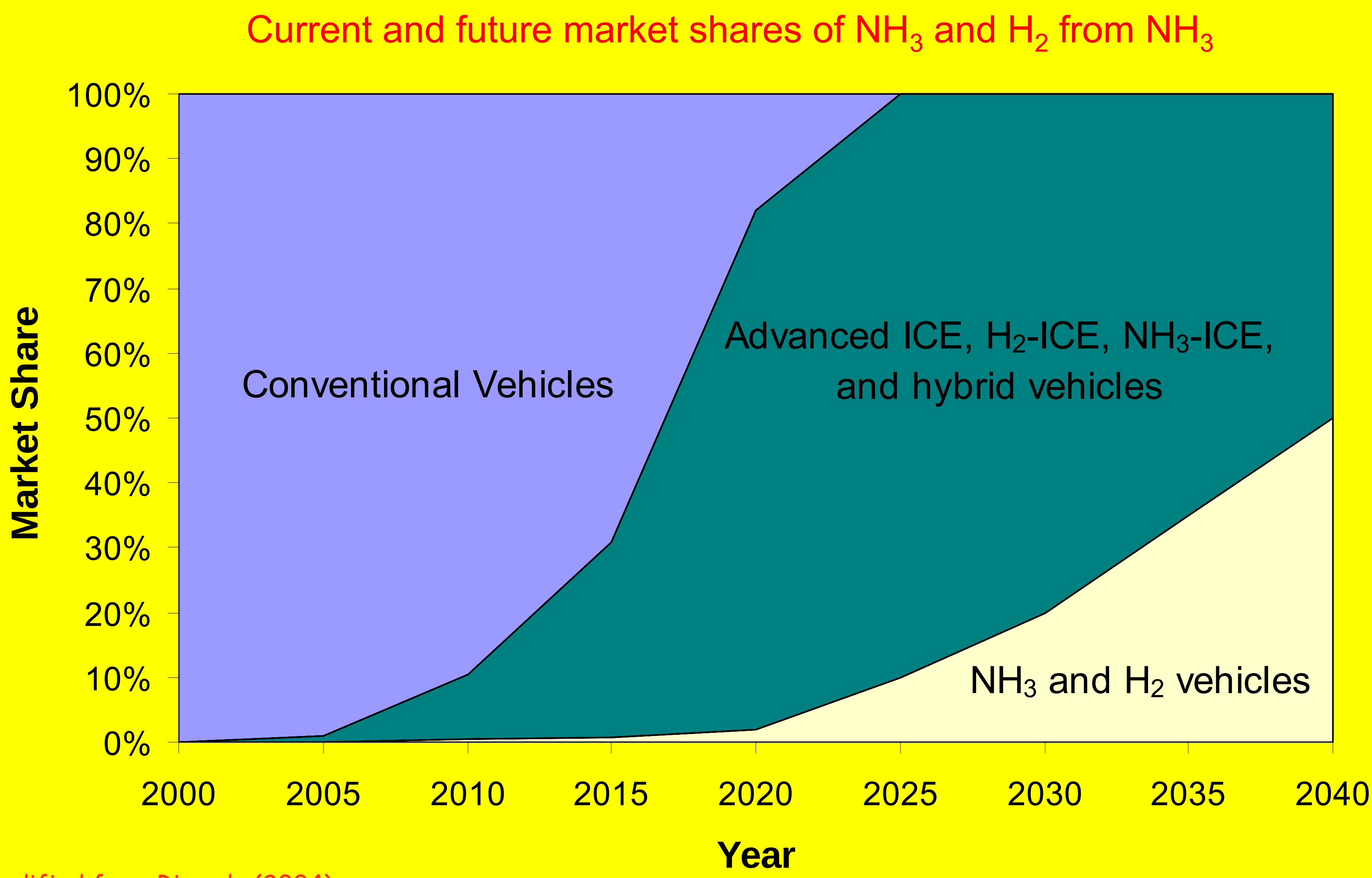
- Overall system: including the square dish, ammonia water heat engine, and either the cone or the cavity receiver

Transitional and Permanent Solutions



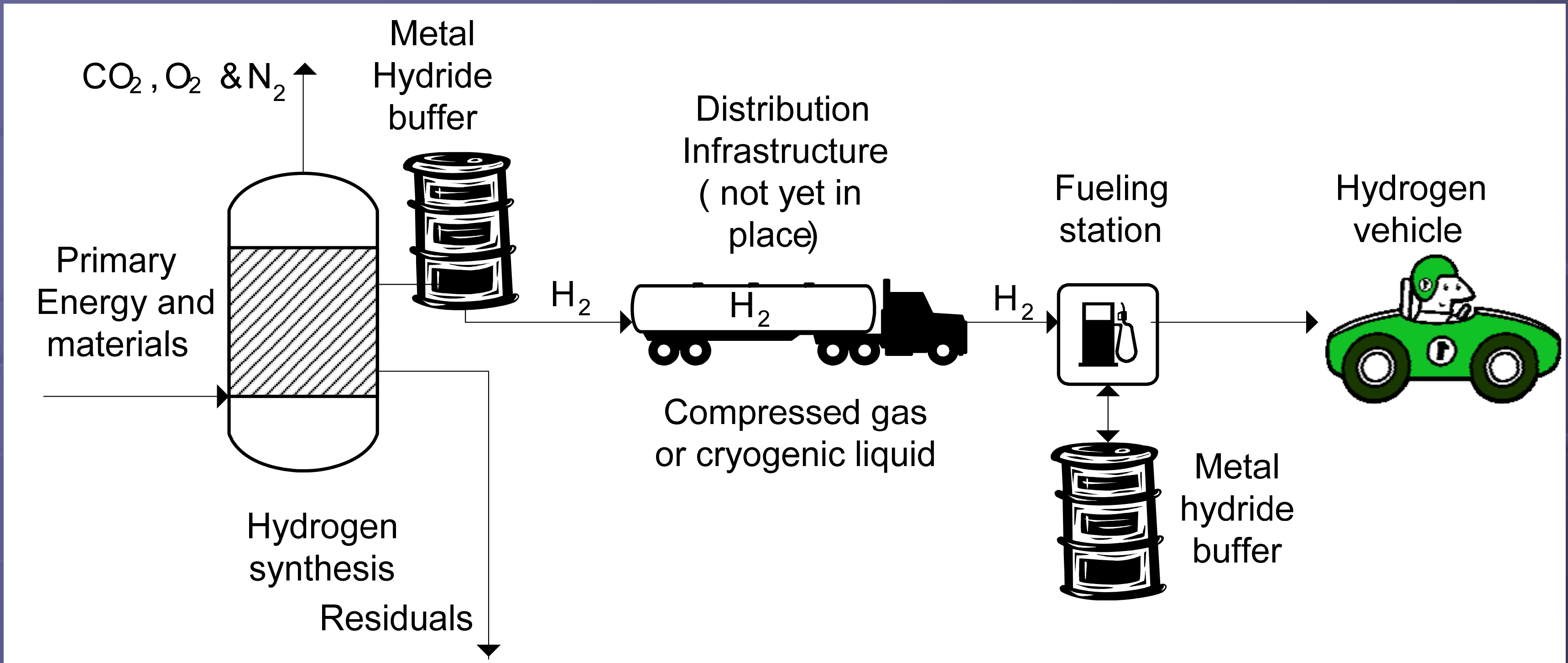
Key items:
- Policies
- Models
- Performance tools
- Technologies
- Infrastructure
- Commercialization
- etc.

Ammonia as a Sustainable Fuel and H_2 Source



Modified from Ricardo (2004).

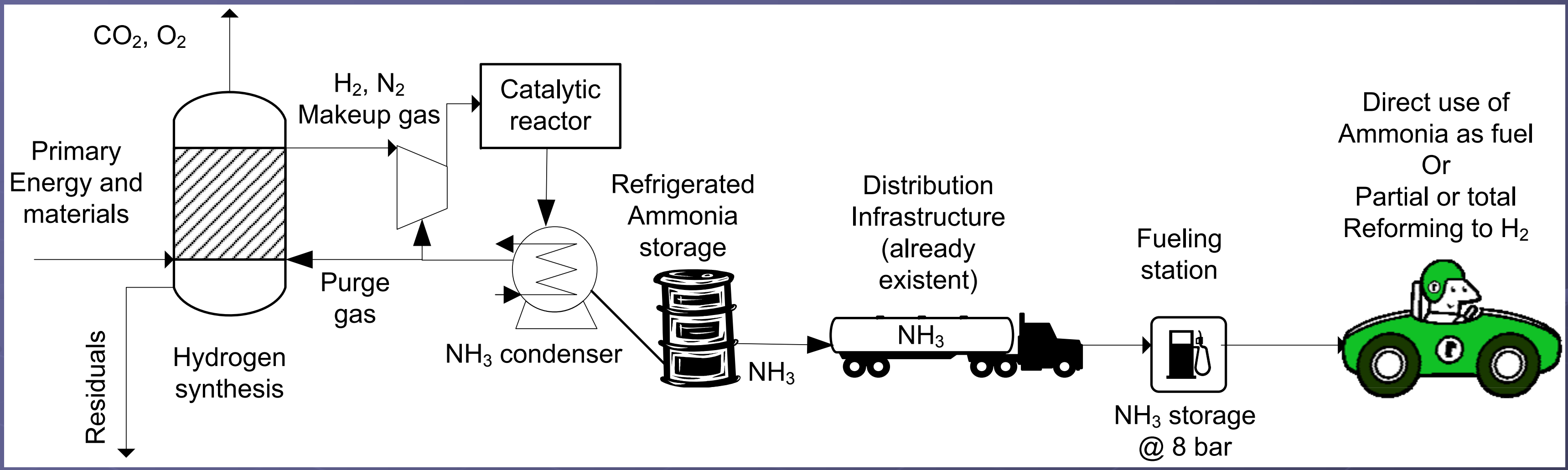
Hydrogen Economy Concept



$$H_2O(l) \rightarrow H_2 + 1/2\,O_2 + 286\text{MJ}$$

Hydrogen is an ideal synthetic fuel. However, implementing a global hydrogen economy currently appears to be non-feasible unless suitable production, distribution and storage technologies are found!

Ammonia as Fuel, H2 Source, Refrigerant, Working Fluid, NOx Reduction Agent, etc.



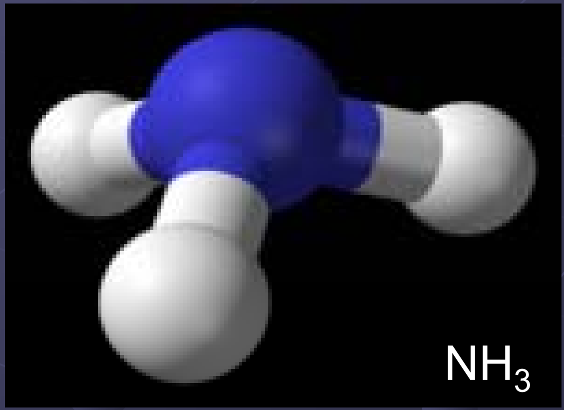
→ 1 mole of ammonia contains 1.5 moles of hydrogen that is 17.8% by weight or 108 kgH_2/m^3 stored in liquid ammonia at 20°C and 8.6 bar.

→The density is 4 times higher than that of the most advanced storage methods in metal hydrides which reach at most 25 kgH_2/m^3.

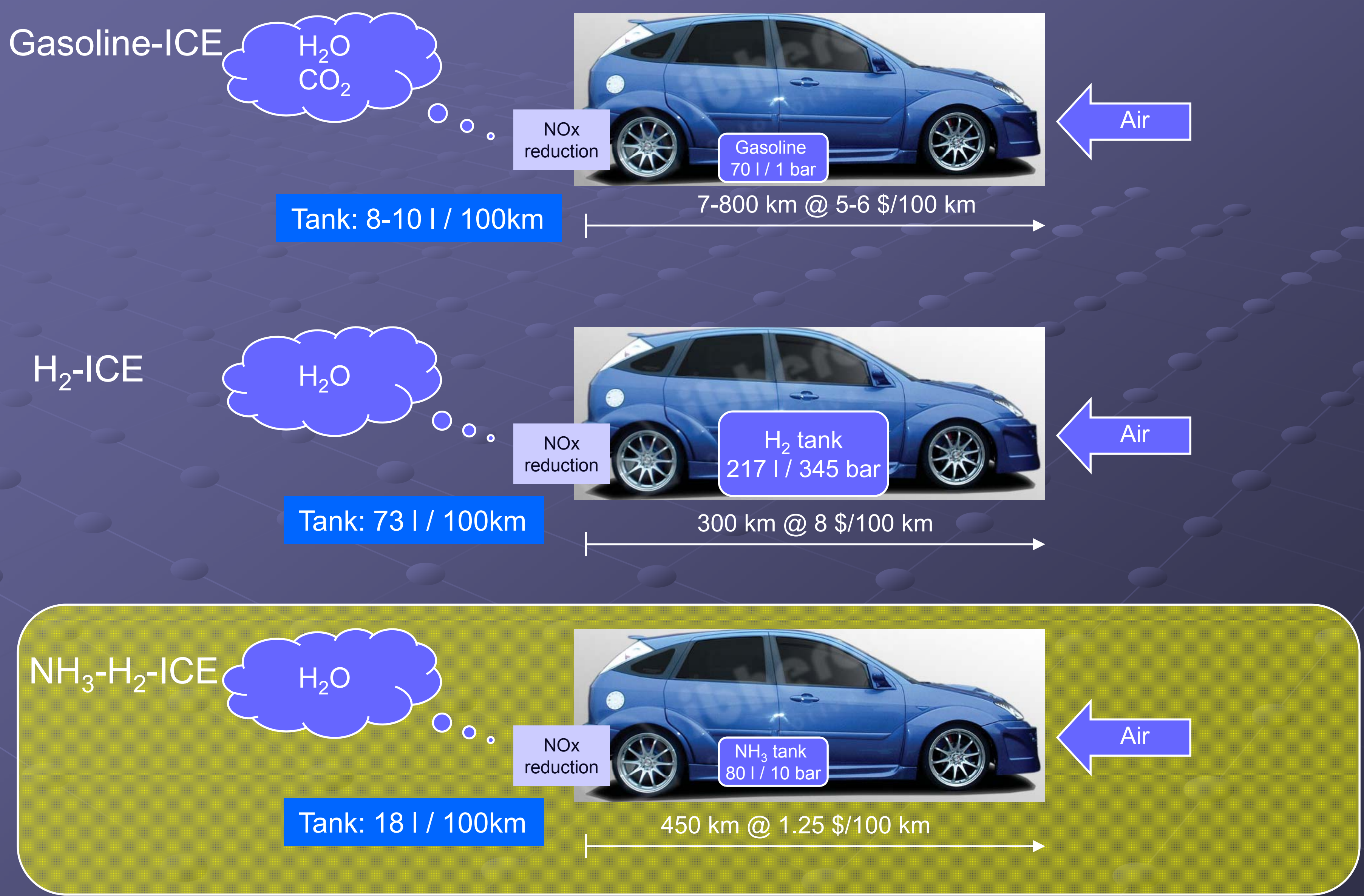
→ High octane rate: 130.

→ It can thermally be cracked into hydrogen and nitrogen.

→ Promoting ammonia as a zero-CO_2 emitting fuel is an attractive and sustainable solution!



Case study: Comparison of Present and Future!

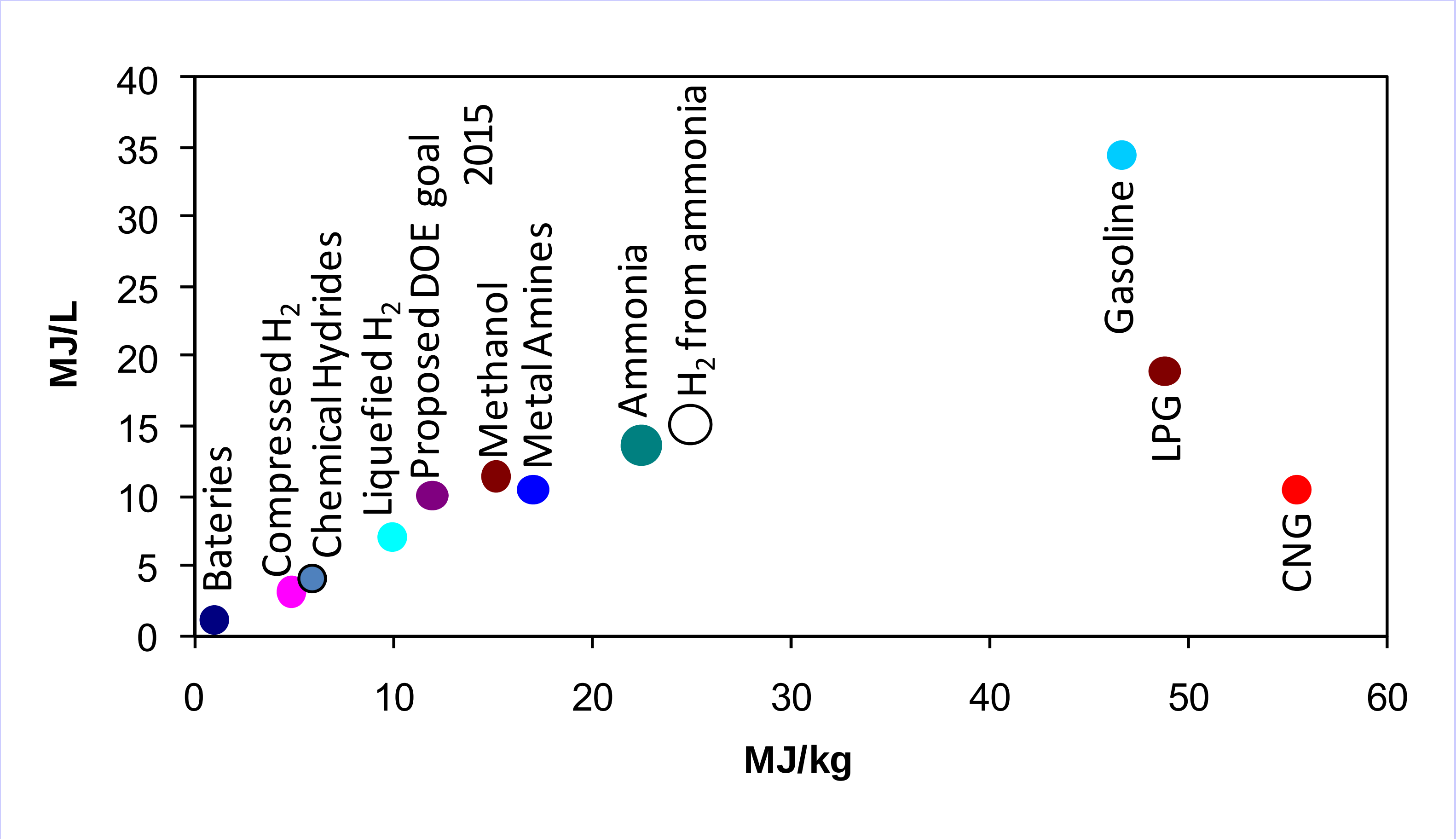


Why NH_3?

→ 1 mole of NH_3 has 1.5 moles of hydrogen or

→ 17 kg of NH_3 stores 3 kg of hydrogen.

→ NH_3 is refrigerant, working fluid and a NO_x reduction agent.

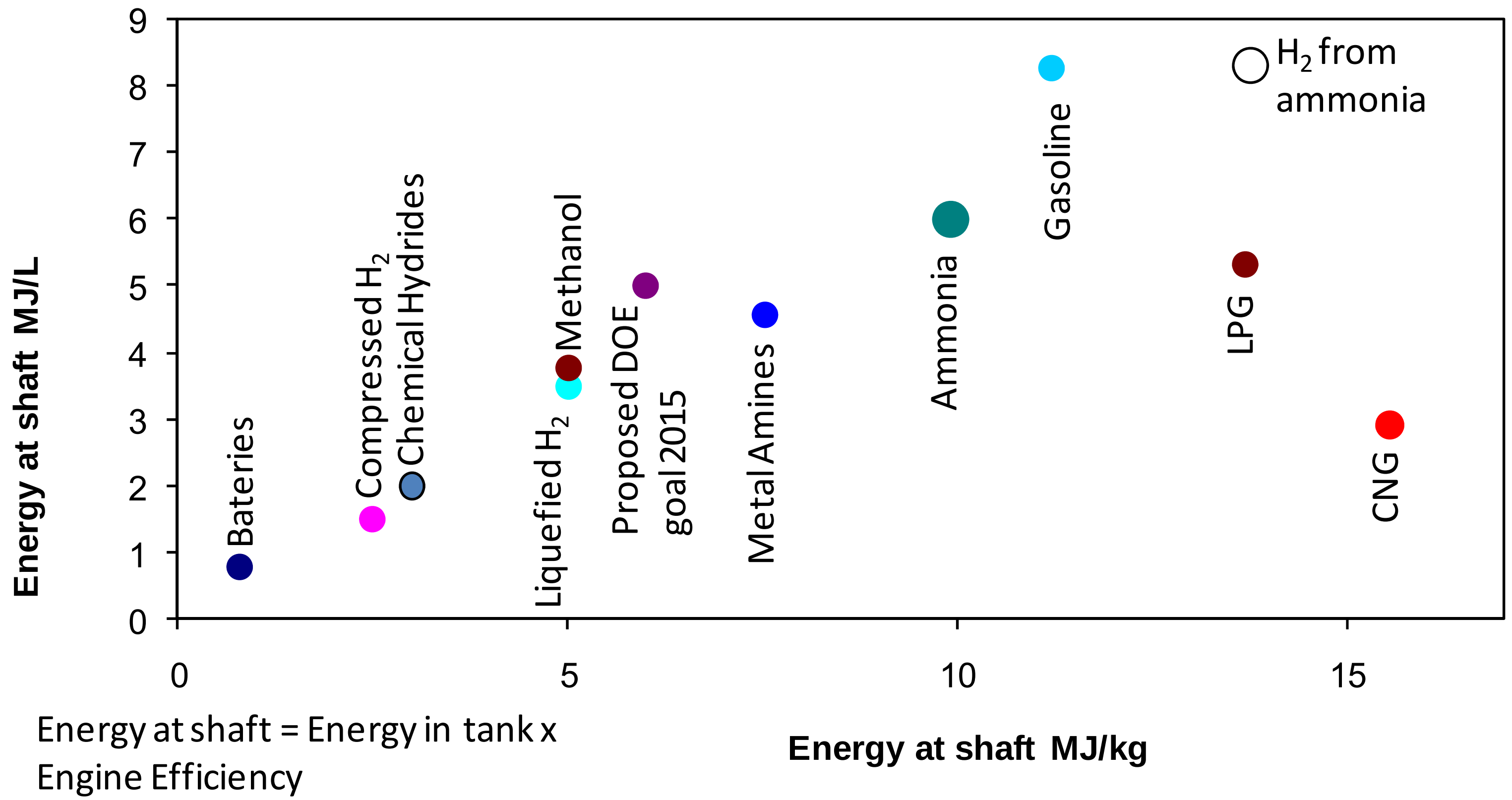


Volumetric energy density vs specific energy density of various fuels.

What about energy delivered to the shaft?

We multiply the energy in tank with the engine efficiency!

Assume; a hydrogen engine efficiency of 50% and a gasoline engine efficiency of 25%.



Volumetric energy density vs specific energy delivered to the shaft for various fuels.

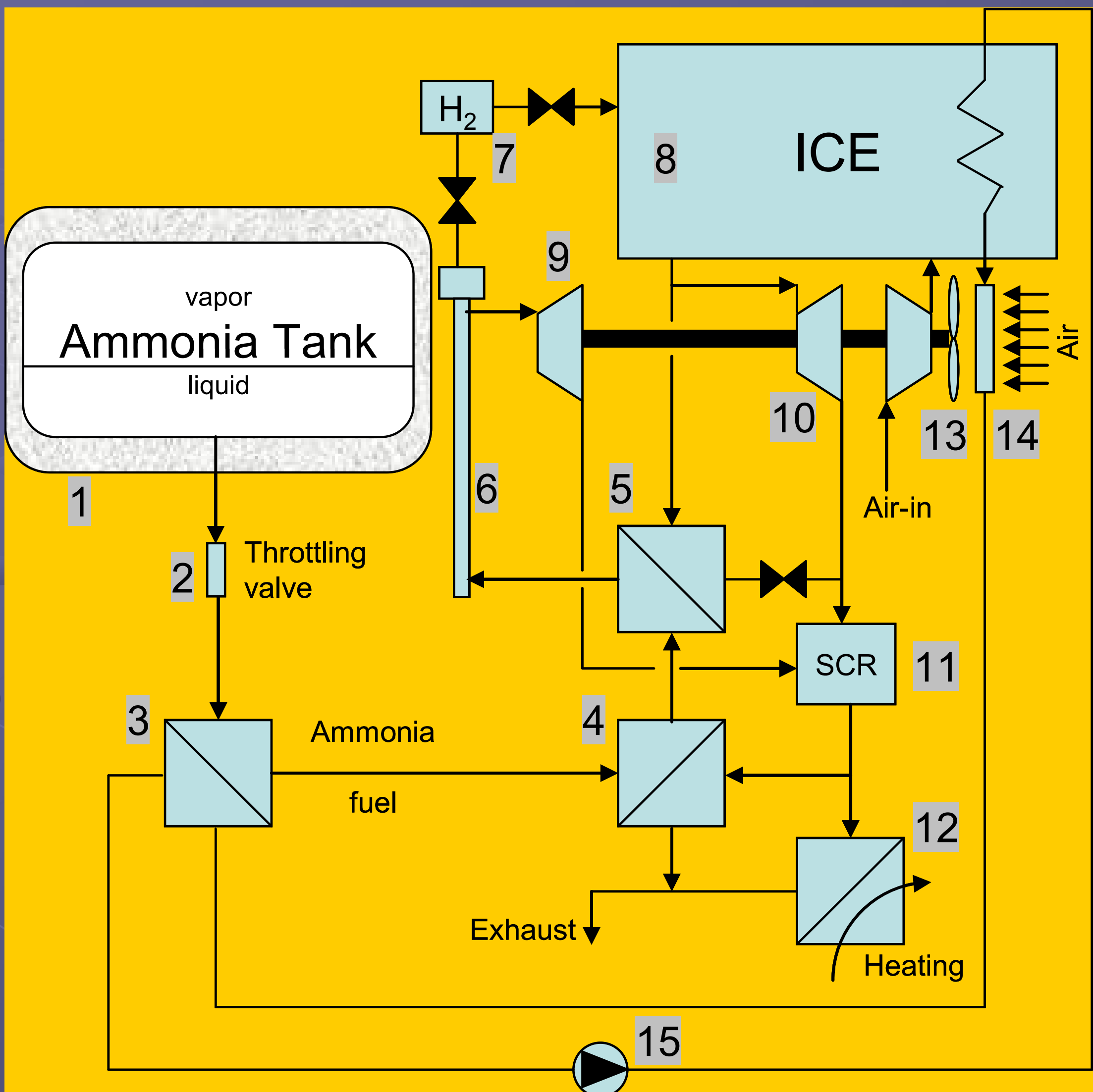
NH_3 vs Other Options

Fuel/Storage	**P [bar]**	**Density [kg/m3]**	**HHV [MJ/kg]**	**Energy Density [GJ/m3]**	**Specific volumetric cost [$/m3]**	**Specific energetic Cost [$/GJ]**
Gasoline,C8H18/Liquid tank	1	736	46.7	34.4	1000	29.1
CNG,CH4/Integrated Storage System	250	188	55.5	10.4	400	38.3
LPG,C3H8/Presurized tank	14	388	48.9	19.0	542	28.5
Metanol,CH3OH/Liquid tank	1	749	15.2	11.4	693	60.9
Hydrogen,H2/Methal hydrides	14	25	142	3.6	125	35.2
Ammonia/Pressurized tank	**10**	**603**	**22.5**	**13.6**	**181**	**13.3**
Ammonia,NH3/Metal amines	1	610	17.1	10.4	183	17.5

Question:
What happens if H_2 for a H_2-ICE car is reformed from NH_3?

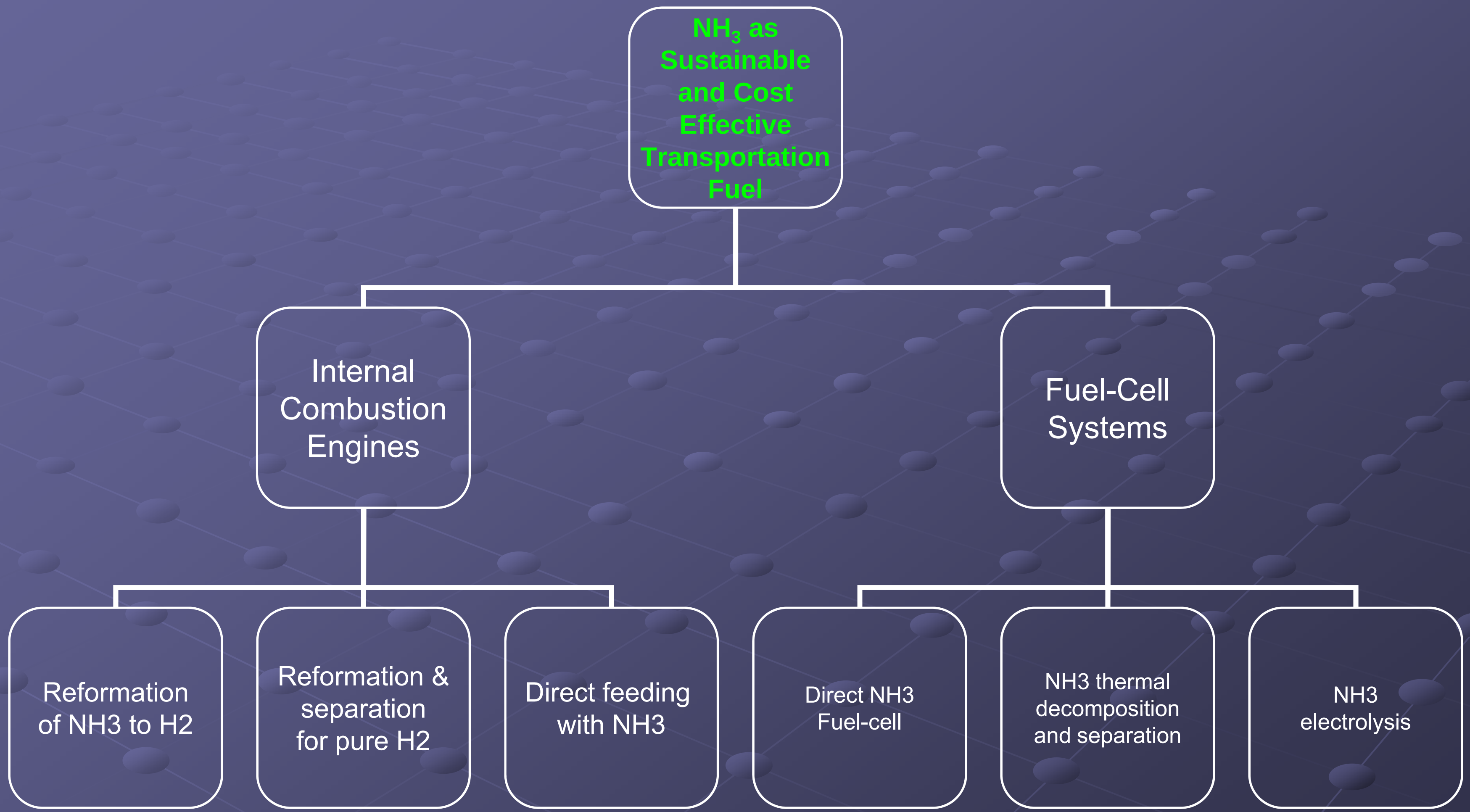
Parameter	Unit	H_2 fuel	H2 from NH_3 as fuel
Storage tank volume	liter	217	76
Storage pressure	bar	345	10
Energy on-board	MJ	710	1025
Cost of full tank	$	25	14
Driving range	km	298	450
Driving cost	$/100km	8.4	1.25
Tank Compactness	Liter/100km	73	18

A Novel Integrated System for Propulsion, Power, Heating, Cooling (and NOx reduction) in Vehicles



1. NH_3 tank thermally insulated
2. modulated throttling valve
3. evaporator for indirect engine cooling
4. NH_3 pre-heater
5. NH_3 heater
6. NH_3 Decomposition and Separation Unit (DSU)
7. hydrogen buffer
8. adapted ICE with hydrogen injection system
9. nitrogen turbine
10. exhaust gas turbine
11. selective catalytic reductor (SCR) for NOx reduction with NH_3
12. heat recovery heat exchanger
13. turbine driven fan
14. downsized air-cooled heat exchanger
15. coolant circulation pump

Better Solutions for Vehicles with NH_3



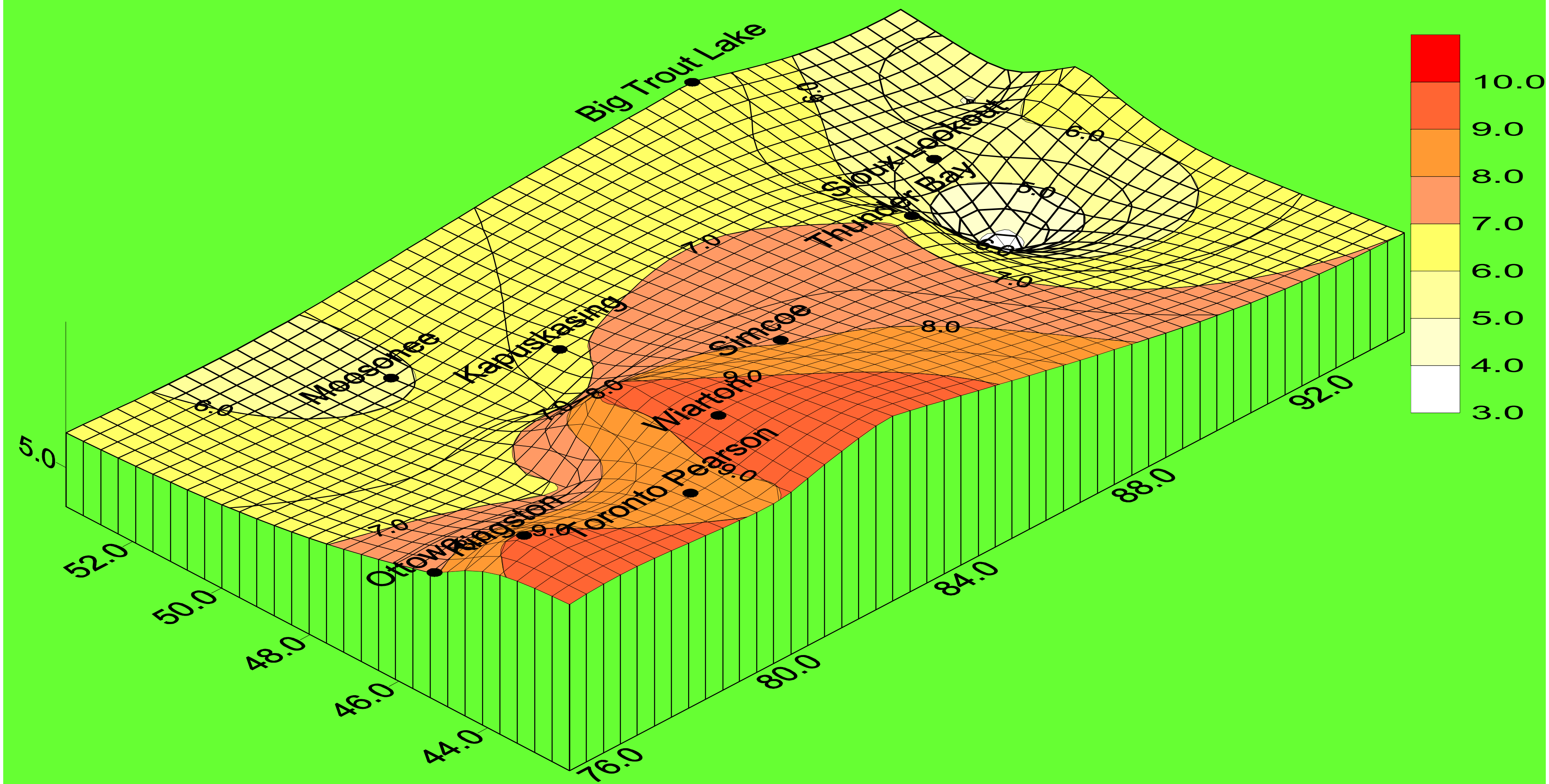
→ To develop new (spatio-temporal) wind exergy maps

Topographical characteristics of selected meteorological stations in Ontario.

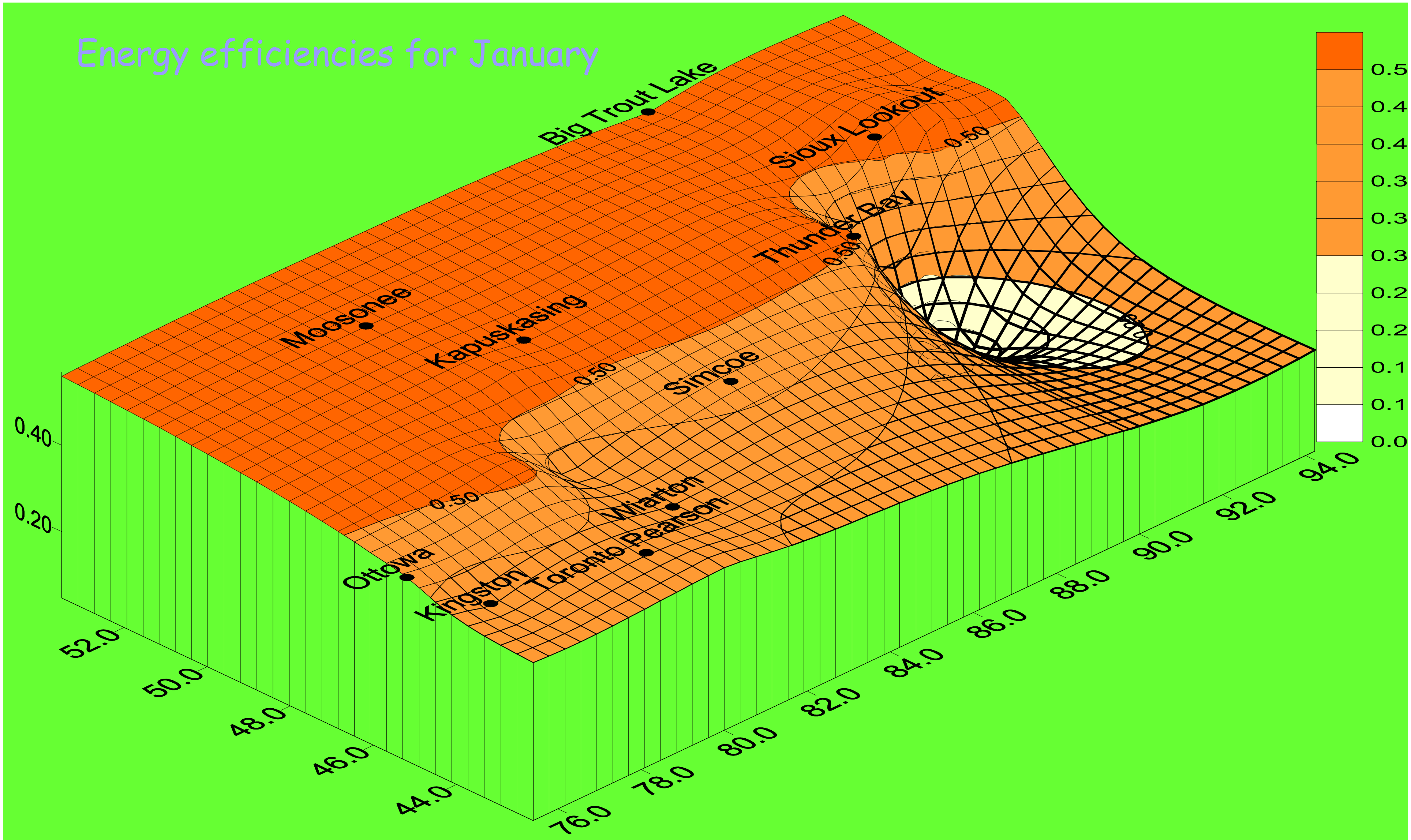
- Windchill effect
- Data for a 100 kW wind power system (rotor diameter: 18 m, hub height: 30 m, cut-in and cut-out wind speeds: 3.5 and 21 m/s
- Maps and performance investigation for 21 locations
- Using 30 year average data for analysis

Station	Lat. (Deg.)	Long. (Deg.)	Altitude (m)
Atikokan	48.45	91.37	395
Big Trout Lake	53.50	89.52	220
Dryden Airport	49.50	92.45	413
Kapuskasing	49.25	82.28	227
Kenora	49.47	94.22	407
Kingston	44.13	76.36	93
London	43.02	81.09	278
Moosonee	51.16	80.39	10
North Bay	46.21	79.26	358
Ottawa	45.19	75.40	116
Red Lake	51.04	93.48	375
Simcoe	46.29	84.30	187
Sault Ste Marie	42.51	80.16	241
Sioux Lookout	50.07	91.54	398
Sudbury	46.37	80.48	348
Thunder Bay	48.22	89.19	199
Timmins	48.34	81.22	295
Toronto Pearson	43.40	79.38	173
Trenton	44.07	77.32	85
Wiarton	44.45	81.06	222
Windsor	42.16	82.58	190

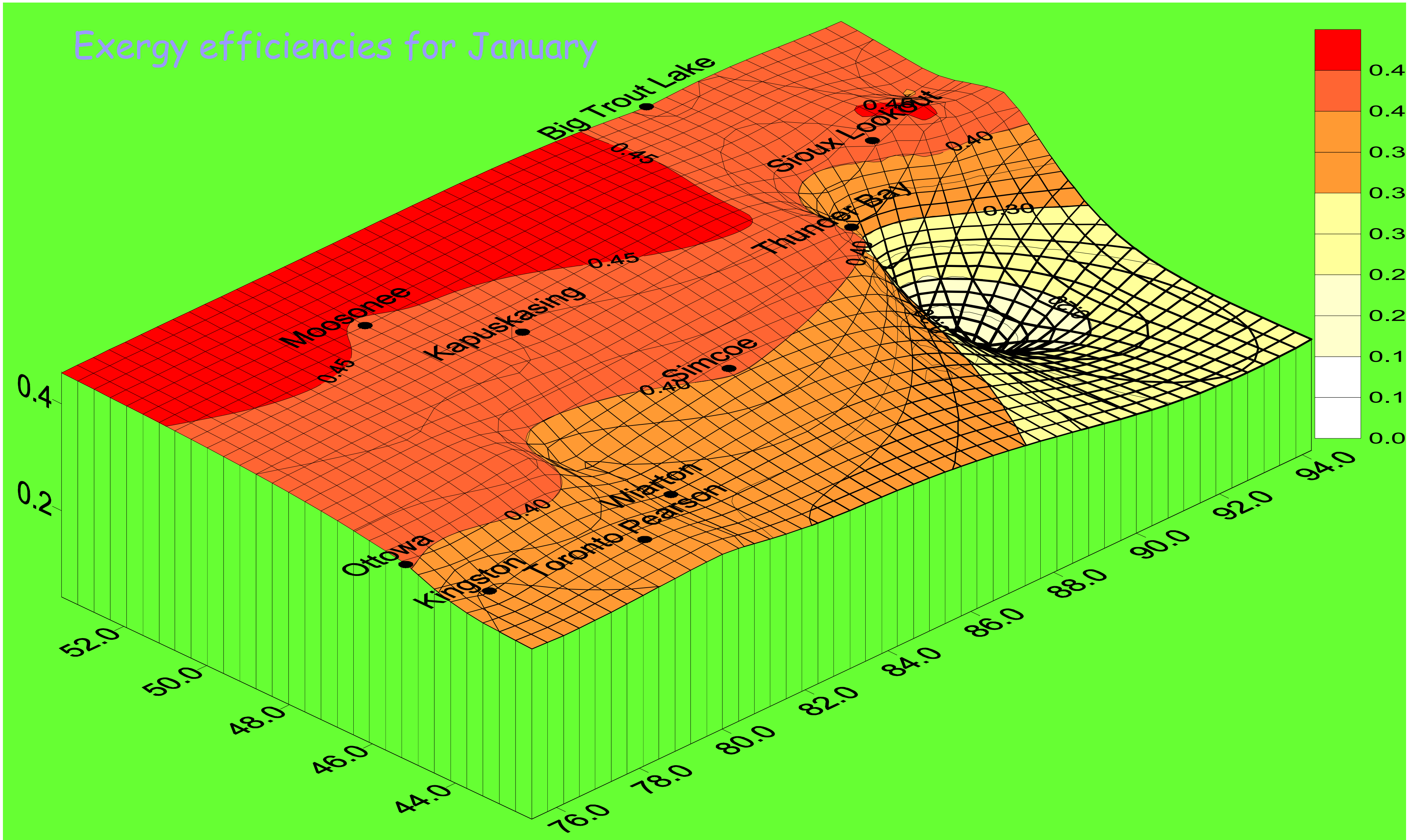
Wind Speed Variation for January



Low wind speeds are observed in the east and north parts of Ontario in January. The monthly minimum average value observed in Atikokan is below the typical wind-turbine cut-in wind speed and as a result there is no electricity generation. The monthly maximum average wind speed observed in southwestern Ontario is 9-10 m/s



Since the average wind speed is below the cut-in wind speed in Atikokan, the station energy efficiency is zero. At low wind speeds, efficiencies are high, but this does not mean that at these values the wind turbine is more efficient than rated for that wind speed. Rather, it means that the generated electricity is low and also the potential of wind energy is low at these wind speeds. As a result, the ratio between generated electricity and potential energy is high.



The same observations apply for exergy and, in addition, the contours for exergy efficiency are seen to be lower than those for energy efficiency for all regions. The average exergy efficiency value is 40%. This exergy map allows interpolation to be used to estimate parameter values in regions for which there are no measured data. Hence, this kind of map can be used for practical engineering applications.

CONCLUSIONS

- Find a right doctor and get a right prescription for cure!
- Change the diet!
- Conserve energy and other resources.
- Diversify energy options. Do not rely on one source!
- Hydrogen economy as a part of solution.
- Ammonia as a potential fuel and hydrogen source.
- Implement right energy policies and strategies!
- Employ sustainable energy systems to help overcome local and global problems.
- Limit political dimensions in decision making process.
- Use life cycle assessment for a complete 3-D picture!

Dedication

To my Family and my HQP (HLP)