Compressed Air Engine: The EOS

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Goals

- ***Design*** a sustainable automobile powered by alternate fuel that does not detrimentally impact the environment
- Propose an ***infrastructure*** that is both practical and reliable and would support a fleet of our alternate fuel cars
- Maintain a high level of ***marketability*** that extends beyond an environmentally conscious group and into mainstream society

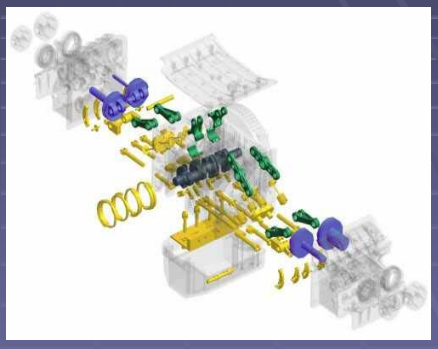
How does it work?

- In an ICE, the combustion of the fuel pushes the pistons down to turn the crankshaft
- In a compressed air engine, the expansion of the compressed air pushes down the pistons to turn the crankshaft

http://www.bagelhole.org/?page=353

What type of air engine?

- Three options for air technology:
  - Air
  - Air and electric
  - Air and gasoline
- Just using air is the best option because it drastically cuts the weight of the vehicle, and thus improves the efficiency and power



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The Compressed Air Engine

- NO EMISSIONS!
  - The air released is actually cleaner than the ambient air because of the filters used
- 4-cylinder
- 70 lbs, compared to 200-600 lbs for other engines
- Uses vegetable oil for oil, and only needs to be changed every 31,000 miles
- The cold air produced can be used for the air conditioning system

http://www.bagelhole.org/?page=353
http://www.cyber-media.com/aircar/
http://www.241computers.com/ford/ContentExpress20-30-38.html

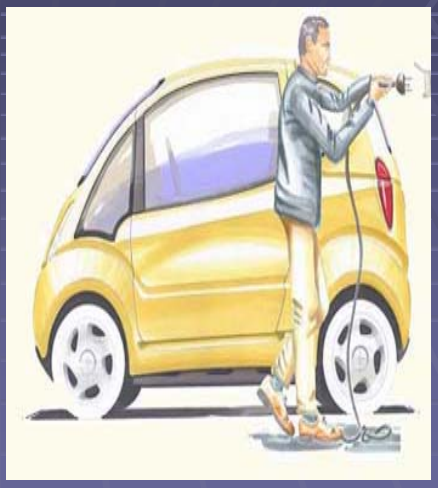
The Car

- Range of 120 miles
- Max speed at least 70 mph
- 0-50 mph in 7 seconds
- Solar panels on the roof can be used for the heating system
- Will look like a normal car
- Made out of recyclable or renewable materials

http://www.bagelhole.org/?page=353
http://www.cyber-media.com/aircar/

Refueling

- Fuel at a service station (3-4 min)
- Plug the car into an outlet (6-8 hrs; overnight)
- Use the onboard solar panels for the electricity to compress the air



http://www.theaircar.com/station.html

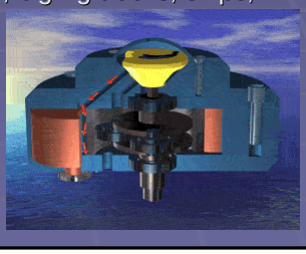
Real World Examples of the Compressed-Air Engine

- MDI (Moteur Développement International)
  - French based company – Guy Nègre
  - Sold licenses to Spain, Portugal, Great Britain, France, and South Africa, among others
    - Production based out of “micro-factories”
    - Has yet to begin
  - Mexico City wants to replace 87,000 taxis
  - Interests among third world countries
    - Cheap and Clean

http://www.theaircar.com/faq.html

(http://www.timesonline.co.uk/printFriendly/0,,1-120-957436-120,00.html)

- EngineAir
  - Australian based company
    - Created an extremely efficient compressed-air engine
    - Not yet in cars
      - Start off in the mining market
      - Prototypes involving small vehicles
- MYT ™ or “Massive, Yet Tiny”
  - Created by Raphial Morgado
  - Replaces a 3000-lb engine with one weighing 150 lb
    - Equivalent of a 32-cylinder four-stroke engine
    - Power to weight ratio 40x greater than conventional motor
    - Useful in large tractor trailers, planes, big-rig trucks, ships, etc.



Magnesium

- Benefits:
  - Extremely Light Material (1/4 as dense as steel, 2/3 as dense as aluminum), and still maintains high impact resistance
  - Don’t have to use excess amounts with its high strength:weight ratio
  - Abundant material supply (sea water, brines, and magnesium-bearing minerals)
  - Close to 100% recyclable
- Disadvantages:
  - Cost is a little high right now, but supply is growing so those costs will decrease with time

Why Not Other Materials?

- Aluminum? Mg has:
  - Better machining
  - Better corrosion resistance
  - Increased die life
  - Can be cast in large thin-walled near net shapes
- Plastic? Mg is:
  - Stronger/stiffer
  - Safer: better absorption of energy
- Steel? No… Mg:
  - No welding/ less assembly/ lower tooling costs
  - Superior dimensional stability/repeatability

http://www.meridian-mag.com/magnesium/

Miscellaneous Ideas

- Magnesium could also be incorporated into the windows to create a switchable mirror
  - "Smart Windows" keep sunlight from overheating car in summer time
  - Energy efficient to maintain desired temperature
- Soy/Hemp Seating, etc.

http://www.aist.go.jp/aist_e/research_units/research_section/mrisus/mrisus_main.html

Power Plants

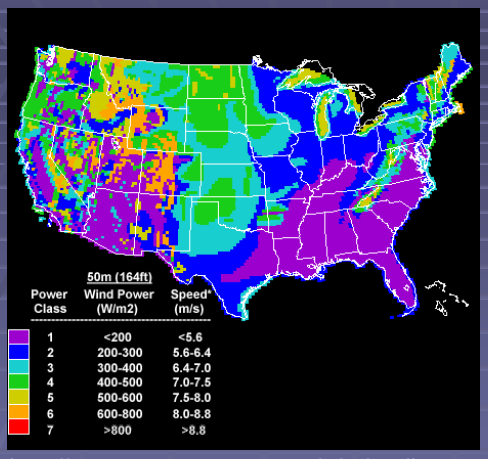
- Point sources of pollution
  - Can be more easily controlled than countless tailpipes
  - Zero emissions can be achieved through cleaning technologies and renewable energies
  - Maximize efficiency with superconductor wiring
  - Localized energy sources, reduce the need for transport
    - Minimize transportation energy use
    - Don't rely on foreign oil

On-Site Energy Production

- Solar or Wind Energy
  - *The Aeolian System* (developed by MDI)
    - Uses only turbine produced energy to compress air at refueling stations
  - Solar could have similar uses

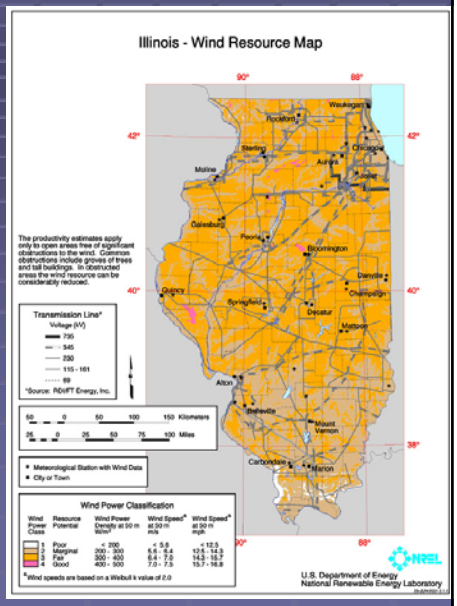
http://theaircar.com/station.html

Wind-Turbine Power



http://www1.eere.energy.gov/windandhydro/wind_potential.html

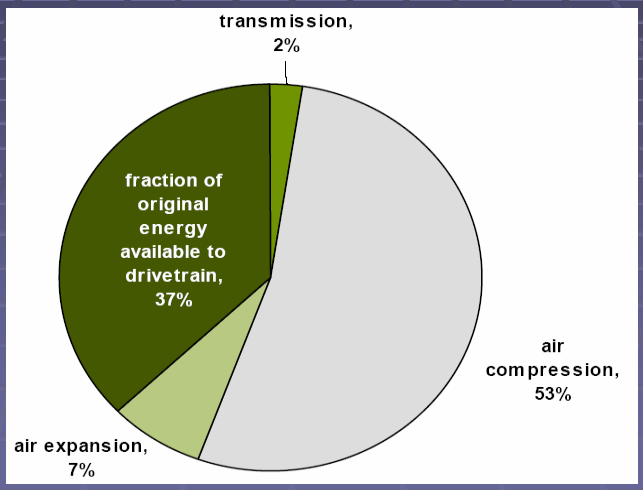
http://www.eere.energy.gov/windandhydro/windpoweringamerica/images/windmaps/il_std800.jpg



Energy of Compressed Air

- If you compress air completely you actually get liquid. So we take the energy value of liquid nitrogen (air consists of 70% nitrogen by volume)
- A way to calculate the energy value of 1 liter of compressed air:
  - ✓Energy Density/Specific Energy of liquid nitrogen = 320 KJ/L or 320,000 joules/liter
  - ✓Energy value of gasoline: 33,333 KJ/L or 33,000,000 joules/liter
- About 100 times more energy available in gasoline than in fully compressed air
- The transfer to mechanical power of compressed air is better than for gasoline

Energy Losses on the Compressed Air Fuel Path



http://www.efcf.com/reports/E18.pdf

Recovering Heat Loss

- Much of the heat lost during the compression of the air can be regained from the operations of the car
- The air in the compression-stage is extremely cold
- The cold air can be reheated from the ambient atmosphere between each step to extract energy from it before being expanded through the next turbine

H2 vs. Air

- Because of the different densities, hydrogen compression requires 15 times more energy than air compression for identical initial volumes and identical pressure limits
- For hydrogen, the main losses are associated with electrolysis and fuel cell use
- The heat generated in the process of compacting air is considered a loss
- Hydrogen fuel technology is much more expensive

Emissions

Passenger Car

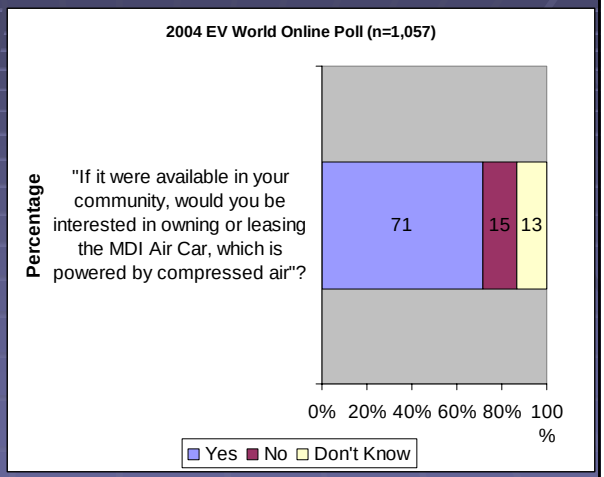
Component	Emission Rate and Fuel Consumption per mile (mi)[1]	Calculation	Total Annual Pollution Emitted and Fuel Consumed
Hydrocarbons	2.80 grams (g)	(2.80 g/mi) x (12,500 mi) x (1 lb/454 g)	**77.1 pounds of hydrocarbons**
Carbon Monoxide	20.9 grams	(20.9 g/mi) x (12,500 mi) x (1 lb/454g)	**575 pounds of carbon monoxide**
Oxides of Nitrogen	1.39 grams	(1.39 g/mi) x (12,500 mi) x (1 lb/454g)	**38.2 pounds of oxides of nitrogen**
Carbon Dioxide[2]	0.916 pound (lb)	(0.916 lb/mi) x (12,500)	**11,450 pounds of carbon dioxide**
Gasoline	0.0465 gallon	(0.0465 gallon/mi) x (12,500 mi)	**581 gallons of gasoline**

Light Truck

Component	Emission Rate and Fuel Consumption per mile (mi)[1]	Calculation	Total Annual Pollution Emitted and Fuel Consumed[3]
Hydrocarbons	3.51 grams (g)	(3.51 g/mi) x (14,000 mi) x (1 lb/454 g)	**108 pounds of hydrocarbons**
Carbon Monoxide	27.7 grams	(27.7 g/mi) x (14,000 mi) x (1 lb/454g)	**854 pounds of carbon monoxide**
Oxides of Nitrogen	1.81 grams	(1.81 g/mi) x (14,000 mi) x (1 lb/454g)	**55.8 pounds of oxides of nitrogen**
Carbon Dioxide[2]	1.15 pounds (lb)	(1.15 lb/mi) x (14,000 mi)	**16,035 pounds of carbon dioxide**
Gasoline	0.0581 gallon	(.0.581 gallon/mi) x (14,000 mi)	**813 gallons of gasoline**

Public Opinion, Consumer Values, and the Preferences of the Market

- Analyzing current consumption habits and public opinion data can help us understand the preferences and values of consumers.
- **Preferences of the Market:**
  - Niche Market: a focused, targetable portion of a market sector that addresses a need for a product or service not offered by mainstream providers. http://en.wikipedia.org/wiki/Niche_marketing
  - EOS Market Niche: Upper, middle class environmental conscious consumers.
  - Public opinion data shows that majority of Americans would buy an air compressed car. http://www.emediawire.com/printer.php?prid=186242



CONSUMER VALUES

- Cost: consumer costs such as cost of car, usage (fuel), maintenance
- Environmentally friendly, sustainable: car production, car emissions, recyclability
- Style / Design
- Power
- Range / Mileage
- Convenience (accessible infrastructure)

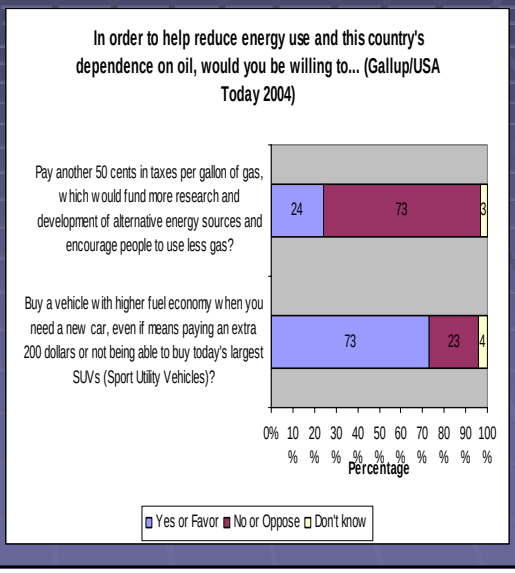
Production Costs

- Production cost of current marketable compressed-air car
  - between $10,000-$15,000
- Production cost of our compressed air car (with solar panels and magnesium car frame)
  - between $15,000-$25,000
- But remember, air compressed cars will benefit from gains in production such as:
  - Improved technology. Investment in research and development of compressed air cars will produce more efficient, cost-saving technologies such as discovery of cheaper materials (to replace limited quantities of current materials like magnesium), improved storage of compressed air, etc.
  - Mass production → Economies of Scale
    - As the total number of vehicles produced increases, the fixed costs will remain the same while the varied costs will increase. This leads to a decreasing total average cost.
    - MDI is creating micro-factories to produce tens of thousands of air compressed cars. Auto Industry benefits from economies of scale at tens of thousands and hundreds of thousands of vehicles produced.

Consumer Values: Cost of Car, Usage, and Maintenance

- Car cost for consumer →
  - Between $10,000 - $25,000
- Usage
  - Fuel → Compressed Air at Service Station
    - Current cost of gasoline: $2.33 per gallon (Chicago 12/06), average mpg is 28 mpg for five passenger car, *9 cents per mile*
    - Cost of fuel: $1.33 per 100 km/62 miles, *2 cents per mile*
    - Majority of public willing to pay higher prices for vehicle itself, but not for fuel. Compressed air car is same price as average vehicle, but cheaper fuel.
- Maintenance:
  - Oil Changes → every 31,000 miles rather than every 3,000 miles

http://www.ethanol.org/documents/ACEFuelEconomyStudy.pdf



CONSUMER VALUES: Cost and Government Incentives

- Government incentives for the purchase of goods can alter and distort consumer behavior towards buying that good.
- Today, most federal and state tax incentives are for the purchase of hybrid vehicles. Tax rebates are up to $4,000 (2005).
- Currently there are no federal or state tax incentives for compressed air cars. But this may change!
- Why? Hybrid cars are already in market and infrastructure for them is in existence. Compressed air cars are not yet on market and infrastructure not constructed.

http://ezinearticles.com/?Rebates-and-Government-Incentives-for-Fuel-Efficient-Car-Owners&id=256783

CONSUMER VALUES: Convenience, Power, Range, Style

- Convenience
  - Since car produces zero emissions, there is no pollution smell.
  - Compressed air engine produces same sound as an electric car → virtually silent.
  - Infrastructure can easily be built.
- Power:
  - Maximum speed of at least 70 mph
  - 0-50 mph in 7 seconds
- Range / Mileage
  - at least 120 miles, 200 km
- Style
  - Family sized Sedan (seats five people) → appeals to consumers' desire for spacious transportation

Judging Success

- Have we met the criteria set out for us? →

  Developing *design*, *infrastructure*, and *marketability* potential that satisfies sustainability criteria and appeals to consumer preferences and values?

- YES!

- Expect the EOS to enter market for sale within the next few years.