Almaden Institute 2009

Why Electric Cars are the solution and how we started Tesla Motors to prove it

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Why start an Electric Car company?

- We wanted to solve a real problem
A Real Problem: Oil
Why Oil Is A Problem

Global Warming

Peak Oil?

Economics

Politics
We use oil primarily for cars
We use oil primarily for cars

Oil for Transportation

- Passenger Cars/Light Trucks: 51%
- Road Freight: 30%
- Air: 13%
- Rail: 2%
- Maritime: 2%
- Pipeline: 2%
If not oil, then what?

- Battery-electric
- Biodiesel

The Right Questions

Q: What is the net resource consumption per mile?
Q: What are net the carbon dioxide emissions per mile?
Q: What is the net reduction of petroleum usage?

- Plug-in hybrid
- Photovoltaic Electric
What about Fuel Cells?
Where does hydrogen come from?

Hydrogen is an *energy carrier* - not a fuel.
What about Fuel Cells?

Q: How many miles will one unit of electricity power a car?
What about Fuel Cells?

Q: How many miles will one unit of electricity power a car?

A: An electric car will go more than 3 times as far as a fuel cell car.
What about Ethanol?

Q: How many miles will one unit of biomass power a car?

Biomass efficiency = \( \frac{\text{miles driven}}{\text{Ton of biomass}} \)

X miles
Q: How many miles will one unit of biomass power a car?

A: An electric car will go almost twice as far as an ethanol car.

- **Ethanol Production**: Best-case Ethanol Production, 50 GGE / ton¹
  - Energy Conversion (highly optimistic)
  - Biomass efficiency = 2500 miles / ton
  - IC Engine
  - 50 miles per gallon
  - 1 ton of biomass
  - 2500 miles

- **Electricity Production**: Gasification Combined Cycle Electric Generation
  - Energy Conversion
  - Biomass efficiency = 4900 miles / ton
  - Electric car
  - 4.9 miles / kWh
  - 1 ton of biomass
  - 4900 miles

1. Iogen enzymatic process, gallons of gasoline equivalent
2. Southern Company Services
What about Ethanol?

**Better Q:** How many miles will one unit of land power a car per year?
What about Ethanol?

**Better Q:** How many miles will one unit of land power a car per year?

- **Ethanol Production:**
  - Corn Farming: 125 bu/acre per year
  - Ethanol Production: 1.94 GGE/bu

- **Ethanol ICE Car**
  - IC Engine: 50 miles per gallon
  - Energy Conversion (highly optimistic) efficiency = 12,000 miles per acre per year

1 acre of farmland:

- **Energy input:** 1.91 GGE/BU
- **Co-product credit:** 0.35 GGE/BU

Number of miles:

- 12K miles
- 2,300 miles

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2. 2.7 gal ethanol/bu / 1.39 gal ethanol/gge
Q: What area is required to offset 50% of Passenger car miles driven in the USA?¹

1. $1.658 \times 10^{12}$ miles in 2002 (DOT Bureau of Transportation Statistics)
2. cia.gov
What about Ethanol?

**Better Q:** How many miles will one unit of land power a car per year?

- **Ethanol Production**
  - Energy Conversion (highly optimistic): efficiency = 12,000 miles per acre per year
  - Corn Farming: 125 bu/acre per year
  - Ethanol Production: 1.94 GGE / bu
  - IC Engine: 50 miles per gallon

- **Ethanol ICE Car**
  - Energy input: 1.91 GGE/BU
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1 acre of farmland

- 12K miles
- 2,300 miles

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2. 2.7 gal ethanol/bu / 1.39 gal ethanol/gge
How about Cellulosic Ethanol?

**Better Q:** How many miles will one unit of land power a car per year?

**Cellulosic Ethanol Production**
- Energy input: ~7 GGE/ton
- 1 acre of farmland
- Energy Conversion (highly optimistic)
  - Efficiency = 58,000 miles per acre per year
- Miscanthus Farming: 15 tons / acre per year
- Enzymatic Ethanol Production: 50 GGE / ton
- IC Engine: 50 miles per gallon

**Ethanol ICE Car**
- 58K miles
- 51K miles

**Electricity Production**
- 1 acre of desert land
- Energy Conversion efficiency = 1.86M miles per acre per year
- Concentrating PV Installation: 380 MWh / acre per year

**Electric Car**
- Electric car: 4900 miles / MWh

**A:** An electric car will go 32 times as far as an ethanol car

1. Dr. Madhu Khana, University of Illinois
2. Iogen enzymatic process, gallons of gasoline equivalent
3. Pinnacle West Capital Corporation
Q: What area is required to offset 50% of Passenger car miles driven in the USA?¹

1. $1.658 \times 10^{12}$ miles in 2002 (DOT Bureau of Transportation Statistics)
2. cia.gov
150 MW
60,000 cars
10 MW
~ 4,000 cars
4.6 MW
~ 1840 cars
924 kW
~ 370 cars
Pearl Harbor
308 kW
~ 125 cars
205 kW
\sim 82 \text{ cars}
Photovoltaic by Individual Choice

2.8 kW
1 car
If not oil then electric cars

Whatever the resource, we must use it as efficiently as possible

Electric cars are by far the best choice

- The lowest resource consumption per mile
- The lowest carbon emissions per mile
- Complete & flexible elimination of petroleum usage

Fossil Fuels  Clean Electricity  Land  Biomass
The Electric Car in 2003
OEM Electric Vehicles available from 1998-2002
Produced to meet California Zero Emissions Mandate

- Toyota RAV4 EV
- Chevy S10 EV
- Honda EV Plus
- GM EV1
- Ford Ranger EV
- Chrysler EPIC EV
OEM Electric Vehicles available from 1998-2002
Produced to meet California Zero Emissions Mandate

2003: California Zero Emissions Mandate rewritten
All OEMs leave the electric vehicle business
What happened to all the electric cars?

"There simply weren't enough [EV-1 customers] at any given time to make a viable business proposition for GM to pursue long-term."

-GM spokesman Dave Barthmuss, Washington Post, 3/10/05

"The car never had appeal beyond a core group of technology enthusiasts and environmentalists."
Imagine the Tesla Roadster
Imagine the Tesla Roadster

0-60 mph acceleration: ~4 seconds
Well-to-wheel efficiency: >135 mpg equivalent
EPA driving range: >200 mi.
Great imagination, now what?
July 2003 – Incorporate!
Technology Feasibility Studies
November 2003: 2 Employees
OEM Partner Study
February 2004: 3 Employees

Business Plan 1.0 Complete
March 2004

Fund Raising: The VC Shuffle
April 2004: 5 Employees
Series A funding led by Elon Musk
May 2004

Early Styling Study Begun
June 2004: 5 Employees
Technology Implementation Studies
July 2004: 9 Employees
Moved to first San Carlos office
July 2004

Lotus-based Mule 1 Started
October 2004: 15 Employees
Begin Drivetrain Component Design
November 2004

Lotus-based Mule 1 Drivetrain Fitting
December 2004
Automotive Stylist Beauty Contest
December 2004

Winning Stylist: Barney Hatt
January 2005: 18 Employees

First Drive! Lotus-based Mule 1 Completed
January 2005

¼ Scale Clay Model Begun
February 2005: 23 Employees
Series B Round Led by Elon Musk
February 2005
Opened UK Office on Lotus Campus
March 2005: 24 Employees

Vehicle Packaging
April 2005

Full-Scale Clay Begun
June 2005

Clay Work Completed
July 2005: 38 Employees

Aerodynamic Tuning Underway
August 2005: 41 Employees
Motor Process Developed
December 2005: 63 Employees

Fiberglass Mule 2 Body Begun
January 2006

Drivable Mule 2 Completed
April 2006

EP1 at Assembly Line Bond Station 1
May 2006: 92 Employees

EP1 Completed
May 2006

Series C Round Led by
Vantage Point Venture Partners & Elon Musk
July 2006
Public Launch with EP1 & EP2 in Santa Monica
August 2006: 100 Employees
EP3 FMVSS Testing

30 MPH Head-on Collision
September 2006: 120 Employees
Radiated Emissions & Susceptibility Testing
October 2006

EP4 & EP5 Durability Testing
October 2006
Issues with transmission emerging
November 2006: 144 Employees

Ongoing EP5 Durability Testing
December 2006

EP2 at Los Angeles Auto Show
January 2007

Arctic Circle: Arvidsjaur, Sweden

Cold-weather drivetrain performance
• ABS tuning
• Traction control tuning
February 2007: 205 Employees
First Transmission Redesign Underway
February 2007
VP1 Motor Build
March 2007: 230 Employees
VP1 Completed and Ready to Ship
April 2007

Series D Round Led by Technology Partners, Musk, Vantage Point
June 2007
Taiwan Motor Factory Up and Running
July  2007

New 2 Speed Transmission Running on Dyno
Taiwan Motor Factory Shipping Product

July 2007
August 2007: 260 Employees
VP 10 Completed
August 2007

30 MPH Side Impact
September 2007

Measured acceleration:
0-60 mph in 3.86 seconds
October 2007

- Production Transmission Fails!!
- Transmission Options Evaluated
- Redesign Underway with One Speed
January 2008: 260 employees
- Completed VP FMVSS verification
- Completed VP durability validation
April 2008

Bridge Financing Led by Elon Musk and Valor Equity Partners
May 2008

- New Rev 1.5 Drivetrain Being Tested
- Interim Transmission Approved
- Regular Production Started!
- Retail store opened in Los Angeles, CA
June 2008

- First Customer Deliveries
- Retail Store Opened in Menlo Park, Ca
September 2008

- 24 Roadsters Delivered
- Production 4 per Week Moving to 10 per Week
- 2008 U.S. Production Sold Out
- 2009 U.S. Production Selling Fast
- 2009 European Production Selling Fast
March 2009

- Hundreds of Roadsters delivered
- Model S sedan announced
- Projected 300 mile range
- Production planned for 2011
June 2009

- More than 600 Roadsters delivered
- $465M in US Department of Energy Loans
- $50M investment from Daimler
- Showrooms opened or planned in 8 US cities
- Showroom opened in London
But does this solve the problem?

What impact can a $100,000 sportscar have?
No, but it has helped things along

- Germany plans for 1 million EVs by 2020
- DOE has released $2.4B in EV related funds
- Every major car OEM has an EV program
- Most OEMs have announced EV models
2007: "When Tesla announced they were building a car, that kind of tore it for me. I thought, ‘If some little West Coast outfit can do this, we can no longer stand by.’"

Mitsubishi iMiev 2009
Nissan Leaf 2010
Daimler’s Electric Smart 2010
But, there are a lot of cars!

- Worldwide over 800M cars and light trucks
- Worldwide sales of 70M per year (2008)
- 260B gallons of gasoline and diesel per year

Maybe 200,000 EVs on the road by 2012, or 0.025% of the fleet

Source: 2008 Global Market Data Book, Automotive News,
Why so few EVs?

The batteries aren’t good enough (yet?)
- Big
- Heavy
- Expensive
- Short lifespan
But there is good news, right?

- Lots of new research
- Battery startups attracting VC dollars
- Enormous worldwide political interest
- Huge market potential
- Step change on any metric can change the game
EV design is a compromise

- Energy density
- Power density
- Cycle and calendar life
- Cost per kWh
But some things work for us

- Electric drive is 6x more efficient than gas drive
- Motors are small compared to engines
- Average daily driving less than 100 miles
- Most households have more than one car
- Long trips are done with a favored vehicle
The future is about sustainability

What could be a bigger opportunity than re-inventing the world?