Why Hydrogen?

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CARB Hydrogen Highway Network Workshop

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Environmental Goals SB 76

- 30 % reduction in GHG
- 33 % production from new renewable sources
- No increase in toxic <u>or</u> criteria pollutants
- Use of renewable hydrogen generation or energy station concept with electricity production

CALIFORNIA HYDROGEN HIGHWAY NETWORK

Greenhouse Gas and Emissions due to Consumption and New Renewables should be Based on Marginal Analysis

Agency Response: ARB has always based its estimates of upstream emissions from battery EVs on marginal emissions in the South Coast Air Basin. Under the assumptions used most recently by the California Energy Commission, electricity produced for battery EVs would come from extremely clean natural gas turbines. <u>ARB would use the same process for determining the upstream emissions from fuel cell vehicles.</u>

Supplement to the Final Statement of Reasons for Rulemaking, Feb 20, 2004

- Additional electricity consumption increases emissions

- New renewables decrease emissions

New renewables should be not be limited to hydrogen vehicles; also evaluate new renewables as part of other vehicle options.

CO2 Emissions Metrics

- Gasoline
  - CO2: 10.9 kg per gallon, including upstream emissions (GREET 1.6)

- Electricity
  - CO2: 0.442 kg/kWh, Combined cycle natural gas turbine, 7500 BTU(hhv)/kWh, 8% T&D loss

Hydrogen Production with Electricity

- 65 kWh per kg : Stuart datasheet, and as derived from Honda’s published data on solar hydrogen station
  - Includes electrolysis and compression
- In a fuel cell, 1 kg of hydrogen produces about 16 kWh of electricity to drive the wheels (50% efficiency)
- 65 kWh in; 16 kWh out
  Overall efficiency 25%;
  75% of input energy is lost

Daily Usage Scenario for Comparison of Alternatives

- 40 miles travel per day
- 33% of energy to make hydrogen comes from "new renewables", zero CO_2
- 67% remaining energy from California grid at marginal emissions rate

Vehicle Comparison

- Gasoline - Honda Civic
  - 34 mpg combined
- Hydrogen - Honda FCX
  - 56.5 mpkg combined

Honda Civic Baseline

- 40 miles at 34 mpg: 1.18 gallons
- 1.18 gallons x 10.9 kg CO2/gallon
  = 12.8 kg CO2
- CO2 per mile:
  12.8/40 = 0.321 kg/mi   or $\boxed{\text{321 g/mile}}$

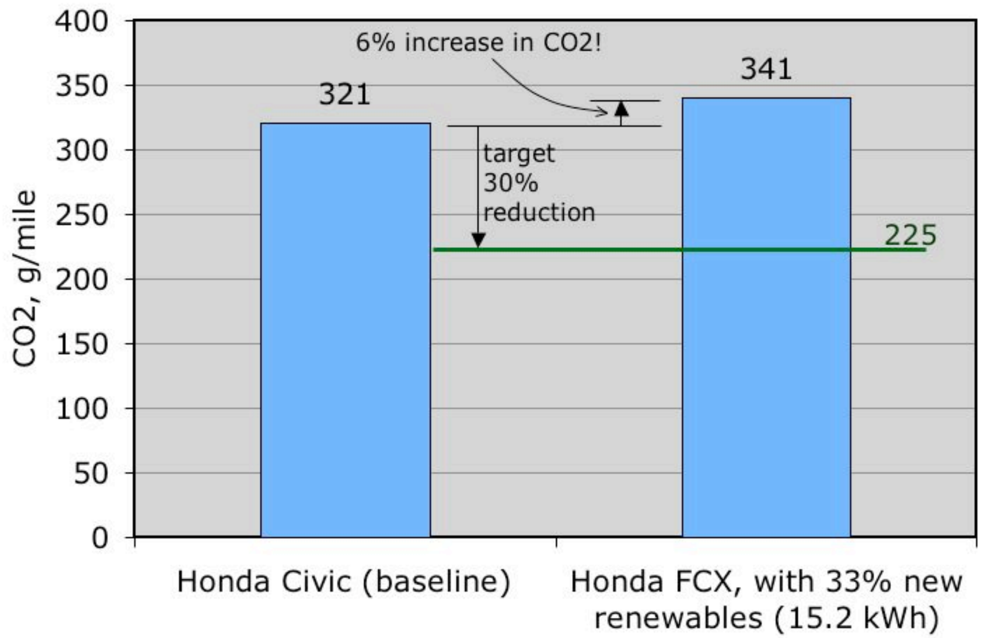
Honda FCX

- 40 miles at 56.5 miles/kg: 0.708 kg H2
- 0.708kg H2 x 65 kWh/kg = 46 kWh

  - 33% new renewables: 15.2 kWh
    - CO2: zero

  - 67% grid electricity: 30.8 kWh
    - CO2: 30.8 kWh x 0.442 kg/kWh = 13.6 kg
- CO2 per mile:
  – 13.6 kg / 40 miles: 341 g/mile

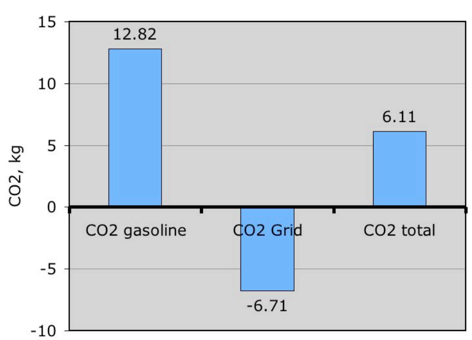
Hydrogen Vehicle Produces MORE CO_2!

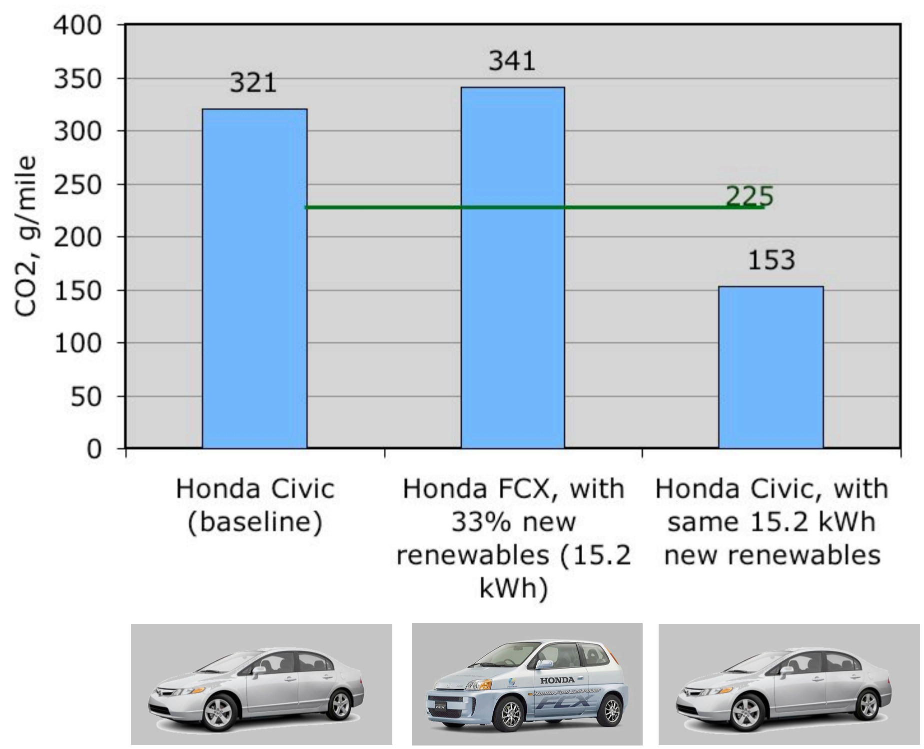


- Can't we do better than this using same amount of "new renewables"?

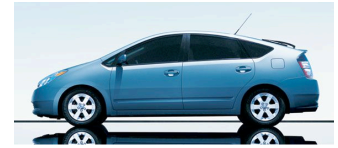
Gasoline Civic, Feed Same 15.2kWh New Renewables to Grid

- 40 miles at 34 mpg: 1.18 gallons, 12.8kg CO2
- 15.2 kWh new renewables to grid
  - CO2 reduction: 1.52 kWh x 0.442 kg/kWh = 6.71 kg reduction
  - Net CO2: 12.8 kg - 6.71 kg = 6.1 kg
- CO2 per mile: 6.1/40 = 153 g/mi

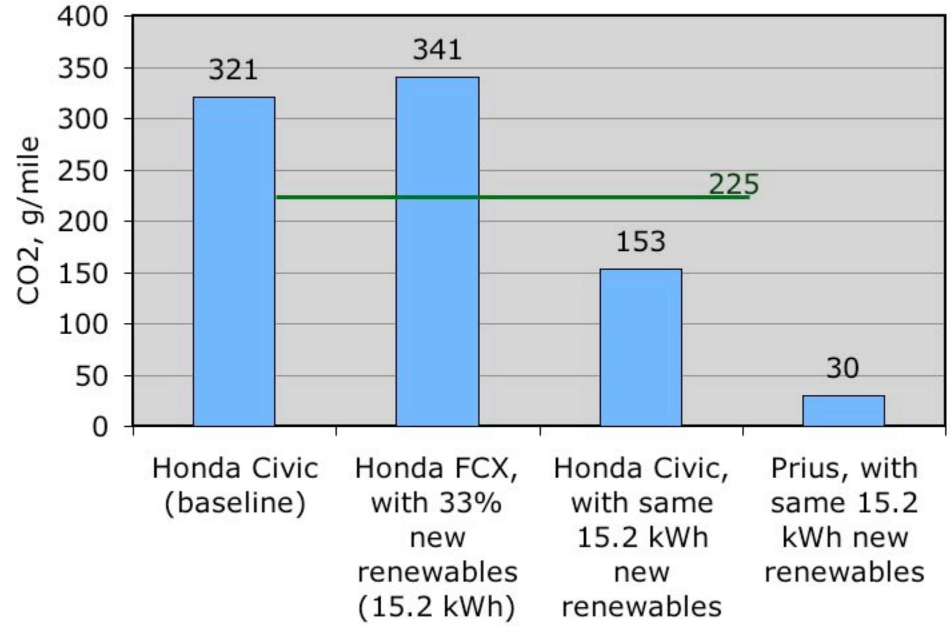


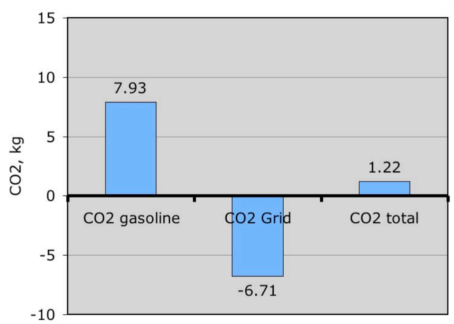


Prius, with Same 15.2 kWh New Renewables to Grid



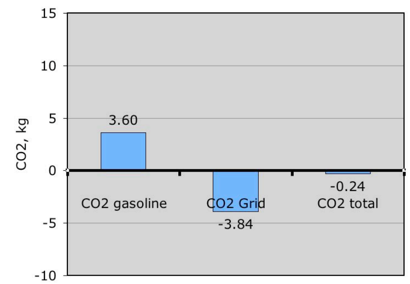
- 40 miles at 55 mpg: 0.73 gallons, 7.93 kg CO_2
- 15.2 kWh new renewables to grid
  - CO_2 reduction: 1.52 kWh x 0.442 kg/kWh = 6.71 kg reduction
  - Net CO_2: 7.93 kg - 6.71 kg = 1.22 kg
- CO_2 per mile: 1.22/40 = 30 g/mi

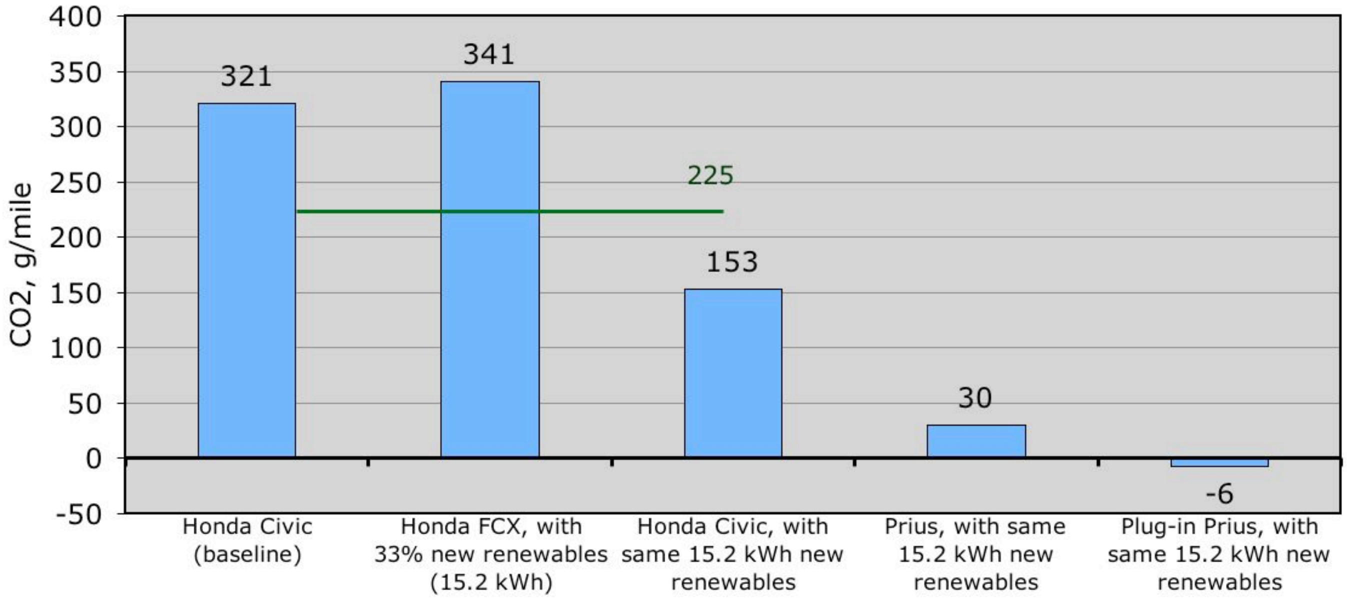




Plug-in Prius

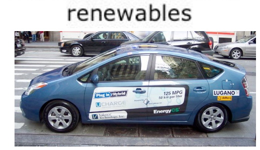
- 40 miles per day requires:
  - 0.33 gallons gasoline (3.6 kg CO_2) and 6.5 kWh electricity
- Same 15.2 kWh new renewables as FCX
  - 6.5 kWh to Prius, remaining 8.2 kWh to grid, offsetting 3.84 kg CO_2
  - Net CO_2: 3.6 kg - 3.84 kg = -0.24 kg
  - CO_2 per mile: -0.24/40 = -6 g/mi





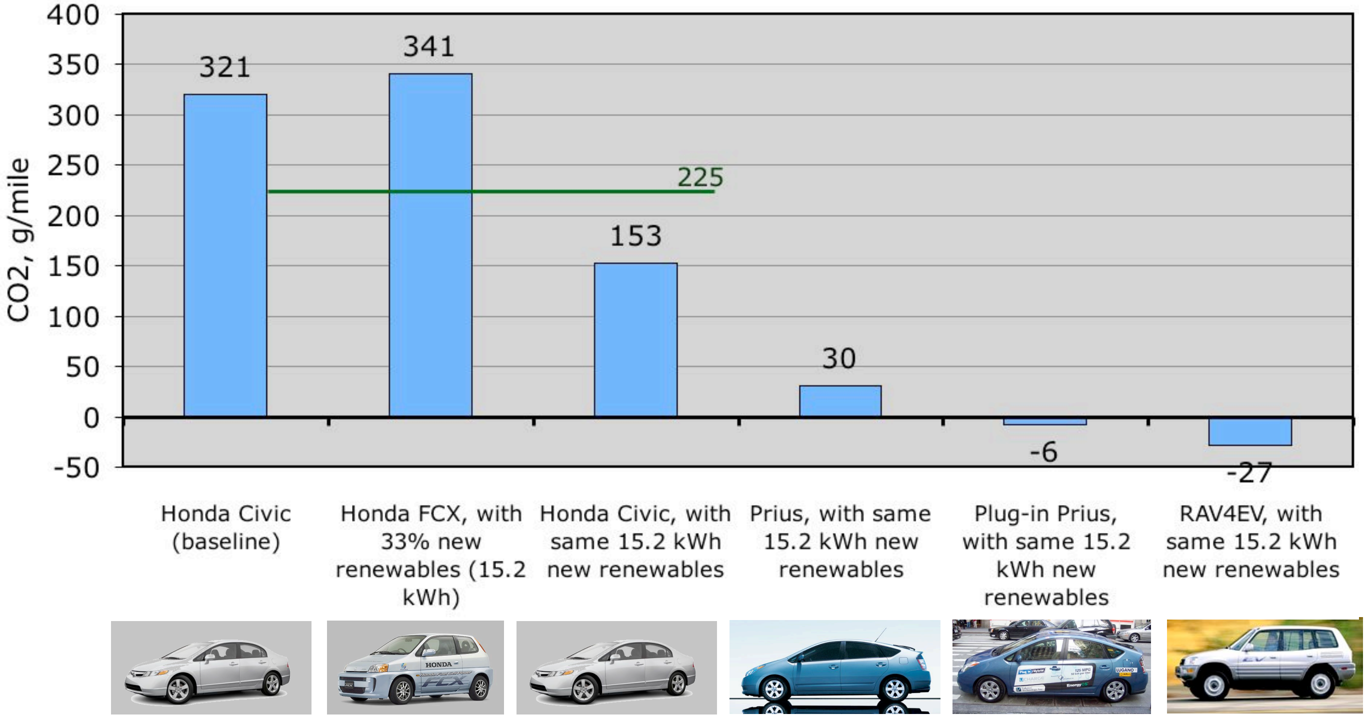






Toyota RAV4 EV

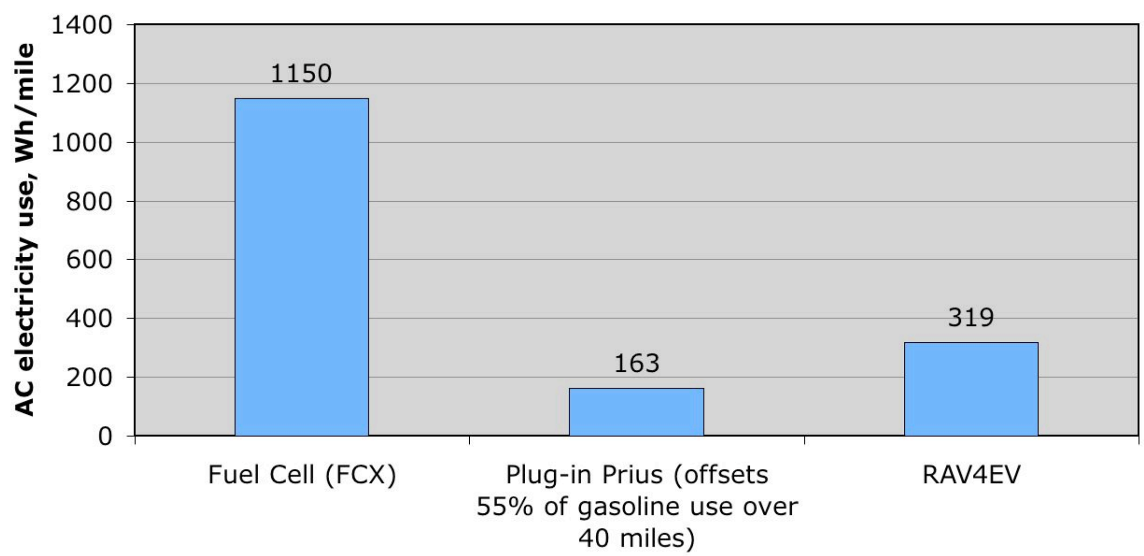
- 40 miles x 0.319 kWh/mile* = 12.8 kWh
- Same 15.2 kWh new renewables as FCX
  - 12.8 to RAV4EV, remaining 2.4 kWh to grid
  - CO_2 : -2.4 kWh x 0.442 kg/kWh = 1.08 kg reduction
  - CO_2 per mile: -1.08/40 = -27 g/mi



* in-use data15k mi, prossen.com/ev/

Comparative Electricity Use

- Fuel Cell Vehicle (FCX)
  - 1150 Wh/mi
- Plug in Prius
  - 0.33 gallon gasoline + 6.5 kWh electricity provides 40 miles
  - Standard Prius with 0.33 gallons would go only 18 miles
  - Plug-in Prius: 6.5 kWh / 40 miles = 163 Wh/mi electricity use, displaces 55% of gasoline that would have been used in a standard Prius
- RAV4EV
  - 319 Wh/mi



Hydrogen Hype

Terry Tamminen, Schwarzenegger's leading environmental adviser, said Californians need only look upward for one huge, renewable source of hydrogen: water, a key component of the fuel. "That's just fuel falling from the sky," he said.

San Diego Union Tribune, Nov 22, 2004

Bargain Pricing

$0.10/kg (but the electrolyzer uses about $8.00 electricity/kg!)

Terry Tamminen, Diamond Bar, Sept 16, 2004

Conclusions

- Making hydrogen is the last thing you want to do with renewable electricity
- SB 76 targets for greenhouse gas and NOx can't be met using 33% new renewables
- The same amount of new renewables needed for 33% of a fuel cell vehicle's energy needs can be more effectively used for plug-in vehicles - negative total CO_2

- California needs to reconsider focus on hydrogen
  – Too inefficient, too costly, too impractical
  – Plug-in vehicles use 1/4 as much energy per mile and are far closer to commercialization
  – The "Hydrogen Highway" should be replaced by the "Energy Independence Freeway" - with main focus on practical and near-term solutions