Institute for Lifecycle Environmental Assessment
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Energy and Land Use Impacts of Sustainable Transportation Scenarios

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Why Land Use?

- Current power production not land use intensive:

Fossil Fuels, Nuclear, etc.

Future scenarios:

- Land use will be a ‘new’ environmental impact.

“Future Cars”

- What sort of energy carriers will the cars of the future utilize?

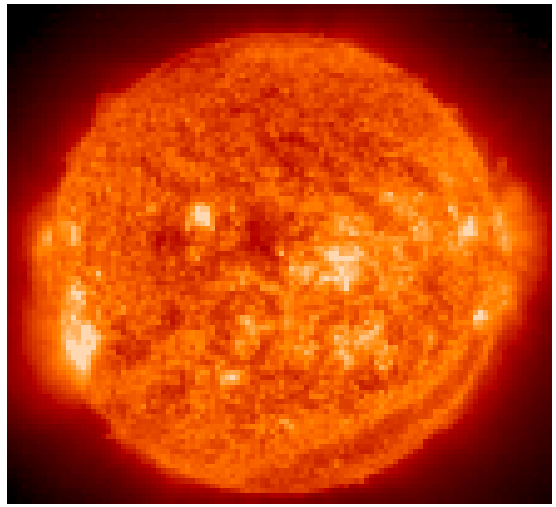
- Hydrogen fuel cell
- Electric Battery
- Bio-fuels

Coming up with land use….

- Any renewable resource has some form of solar radiation as its original source of energy

- This leads to a clear evaluation of the land occupied to acquire a given amount of energy

Solar Radiation



- Solar constant = 1367 W/m^2 incident on Earth's atmosphere

- Typical radiation levels on Earth's surface: approximately 200 W/m^2 (in the U.S.)

Energy conversion:

- Example: 15% efficient solar cell would generate

  $15\%*200 = 30 W/m^2$

- To generate 1 kW = 1000 watts:

  $1000/30 = 33\ m^2$

  This implies one panel of size 33 m^2

What about wind and Biomass?

- Wind turbines don’t rely on direct solar radiation in their location.
- An arbitrary value used for power produced: 5W/m2
- A farm of larger turbines may generate 20W/m2

- Corresponding efficiencies = 2.5% - 10%

Biomass

- Plants convert sunlight into energy via photosynthesis.

- Typical conversion efficiencies: <1%
- Some crops convert up to 4%.

So….plants in fuel tanks?

- Any conversion process has various steps with associated energy losses.

- Well to wheel principle:

"Well to wheel" → "sunlight to motor" + vehicle efficiency

4 process paths:

#1: Electrolytic Hydrogen:

Renewable Electric Generation→ H2 production→ Fuel cell electric vehicle

#2: Electricity:

Renewable Electric Generation→ Battery electric vehicle

#3: Bio-Hydrogen:

Biomass production→ Direct H2 conversion→ Fuel cell electric vehicle

#4: Biofuels:

Biomass Production→ Liquefaction→ On-board H2 conversion→ Fuel cell electric vehicle

Transportation demands

- Current national light vehicle demands:

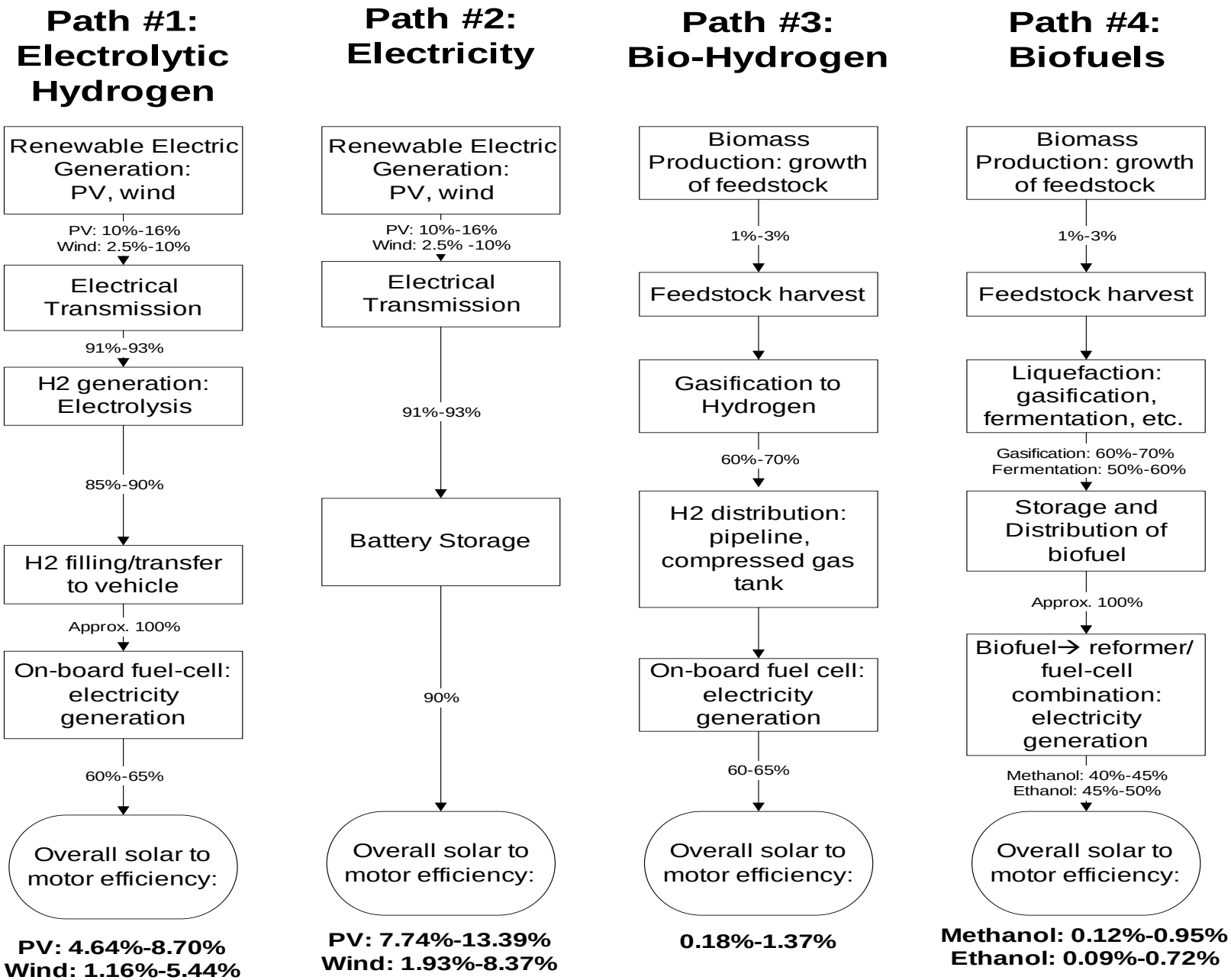
  4 trillion vehicle kilometers traveled (VKT) per year

- 1999: gasoline-powered light vehicle fleet consumed 16.7 EJ in primary fuel.

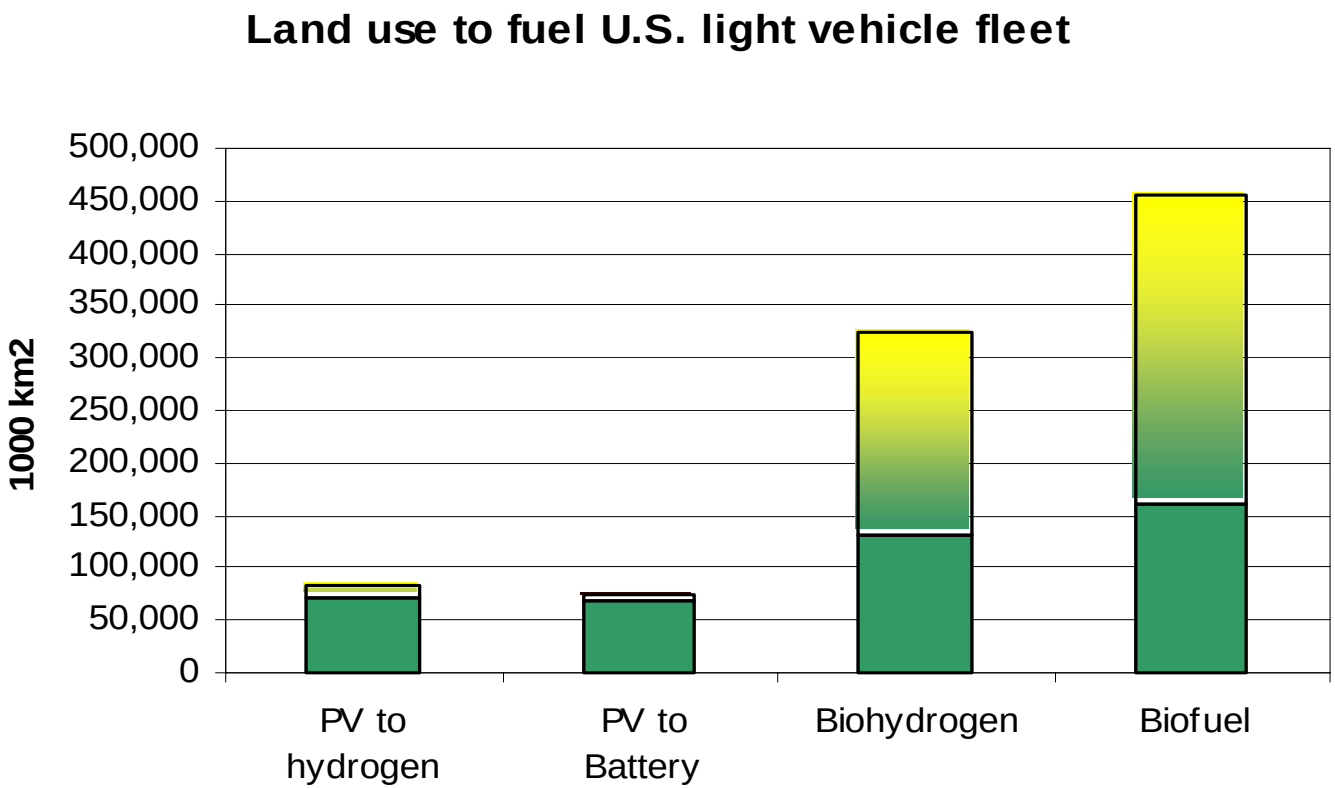
Electric Vehicle Speculation:

- Modern electric vehicles: approximately 4 times as fuel efficient as gasoline vehicles.

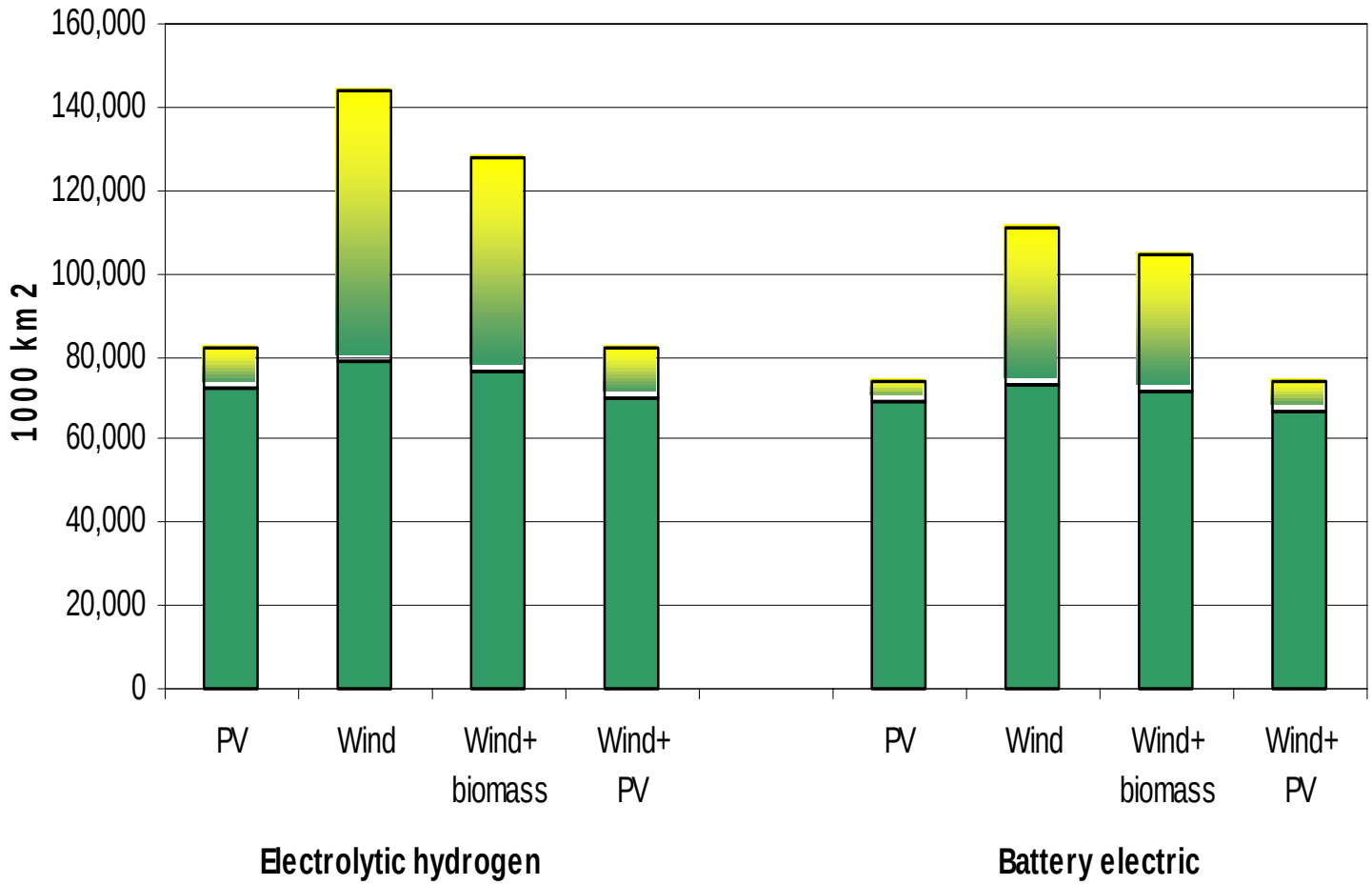
- Therefore, 4 trillion VKT in an electric vehicle would consume ¼ of 16.7 EJ, approximately 4.2 EJ.


Path #1: Electrolytic Hydrogen
Renewable Electric Generation: PV, wind
PV: 10%-16%
Wind: 2.5%-10%
Electrical Transmission
91%-93%
H2 generation: Electrolysis
85%-90%
H2 filling/transfer to vehicle
Approx. 100%
On-board fuel-cell: electricity generation
60%-65%
Overall solar to motor efficiency:
PV: 4.64%-8.70%
Wind: 1.16%-5.44%
Path #2: Electricity
Renewable Electric Generation: PV, wind
PV: 10%-16%
Wind: 2.5% -10%
Electrical Transmission
91%-93%
Battery Storage
90%
Overall solar to motor efficiency:
PV: 7.74%-13.39%
Wind: 1.93%-8.37%
Path #3: Bio-Hydrogen
Biomass Production: growth of feedstock
1%-3%
Feedstock harvest
Gasification to Hydrogen
60%-70%
H2 distribution: pipeline, compressed gas tank
On-board fuel cell: electricity generation
60-65%
Overall solar to motor efficiency:
0.18%-1.37%
Path #4: Biofuels
Biomass Production: growth of feedstock
1%-3%
Feedstock harvest
Liquefaction: gasification, fermentation, etc.
Gasification: 60%-70%
Fermentation: 50%-60%
Storage and Distribution of biofuel
Approx. 100%
Biofuel→ reformer/ fuel-cell combination: electricity generation
Methanol: 40%-45%
Ethanol: 45%-50%
Overall solar to motor efficiency:
Methanol: 0.12%-0.95%
Ethanol: 0.09%-0.72%

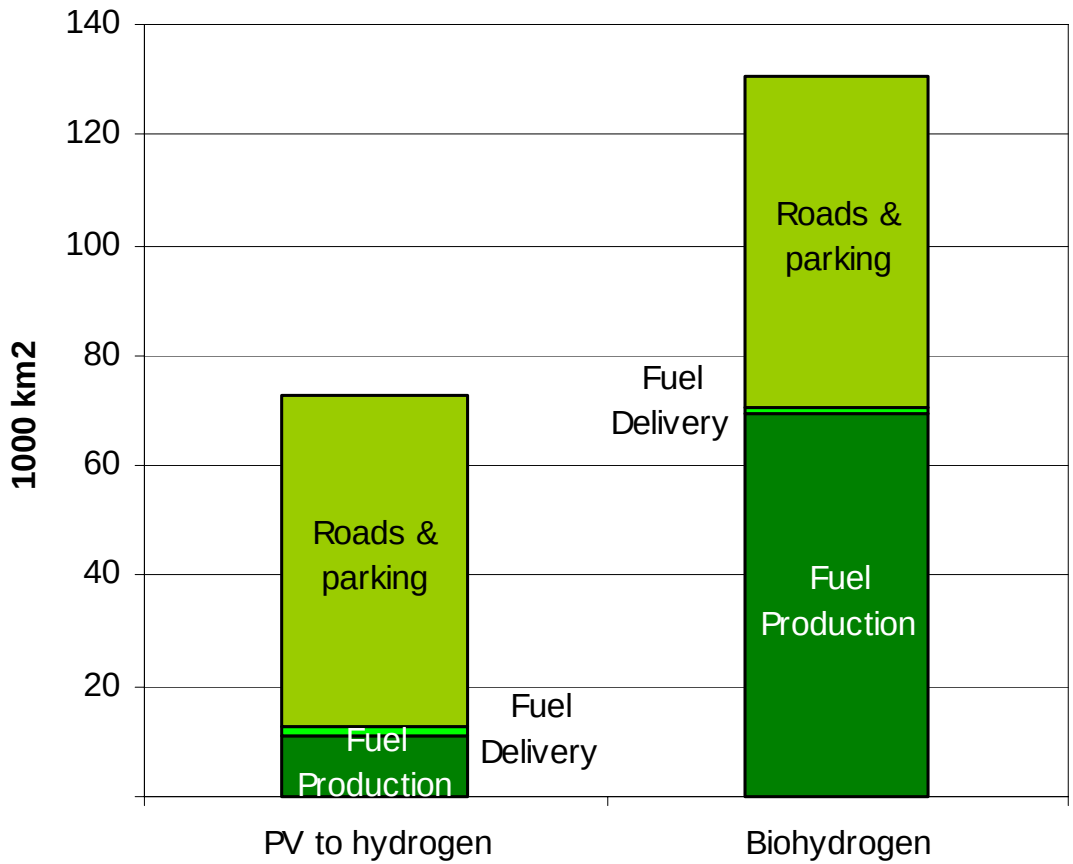
Results


Land use to fuel U.S. light vehicle fleet
1000 km2
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
PV to hydrogen
PV to Battery
Biohydrogen
Biofuel

Land use to fuel U.S. light vehicle fleet



Cause of land use



Conclusions…..

- For large scale applications, we hope to minimize the land occupied.
- Path #2, electricity, has the lowest associated land intensity.
- The Biomass paths have the greatest associated land use.

- Biomass = **BAD**?

  No, but for large scale application, it is quite land use-intensive.

- Hydrogen = **"the future"**?

  Maybe, but it may not be the best solution

Main idea: land use will be the largest environmental impact