

# THE HYDROGEN ECONOMY AND JOBS OF THE FUTURE

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## H<sub>2</sub> Has Distinction of Competing With Nuclear Fusion as Energy Technology That is “Always in the Future.”

- 1960: Engineering magazine predicted widespread military use of H<sub>2</sub> FCs in 3 yrs. & industrial use in 5 years
- Mid 1970's: Energy Research & Development Administration predicted imminent arrival of H<sub>2</sub> economy
- 1998: Iceland announced 10-yr. plan to create H<sub>2</sub> economy & convert all transportation to FC power
- A decade ago: World was “on the cusp of a fuel-cell revolution:” HFCVs poised to dominate market & cheap, clean H<sub>2</sub> power would be available for numerous other applications.

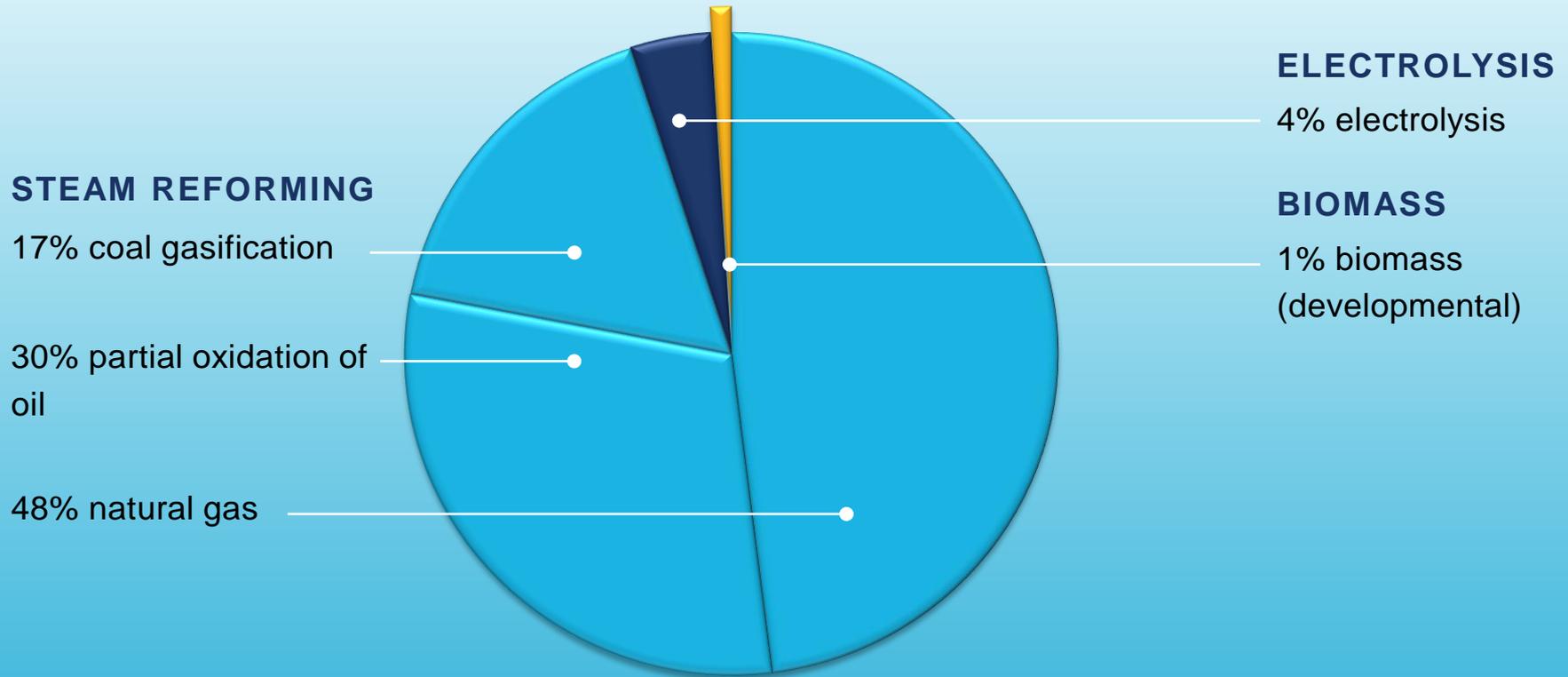
**None of this happened. Why not? What are current prospects for the H<sub>2</sub> economy, & what are the viable H<sub>2</sub> technologies?**

## While H<sub>2</sub> Economy Has Not Arrived, H<sub>2</sub> is Nevertheless Big Business & Growing Rapidly



**Global H<sub>2</sub> market forecast to reach \$155 billion in 2022**

## Current H<sub>2</sub> Production Methods



**Critical problem: 95% of H<sub>2</sub> is produced using fossil fuels, & H<sub>2</sub> is not really “clean and green”**

## 800 lb. Gorilla in the Room That H<sub>2</sub> Advocates & H<sub>2</sub> Industry Promoters Ignore

- H<sub>2</sub> economy hitting brick wall that will severely limit its growth
- Frenzied hype over H<sub>2</sub> FCs, HFCEVs, distributed power, clean fuels, etc. meaningless until method found to efficiently & cheaply produce H<sub>2</sub> in truly green manner that does not increase CO<sub>2</sub> emissions
- Experimental methods involving wind, solar, biomass etc. still far from being economically feasible
- Sustainable H<sub>2</sub> can be produced from scrap/recycled aluminum: This represents potential solution to the problem confronting H<sub>2</sub> economy



## Previous H<sub>2</sub> Jobs Research

- 2008: DOE estimated jobs impacts of H<sub>2</sub> transformation of U.S. economy 2020 – 2050 & found training was needed for new skills
- Subsequent DOE reports found H<sub>2</sub>FC applications hold large job growth potential & industry expected to grown significantly: 250K+ jobs by 2050
- Recent DOE “comprehensive” U.S. energy & employment reports (USEER) barely even mention H<sub>2</sub> or FC jobs
- DOE developed models for estimating jobs impacts of H<sub>2</sub> & FC:
  - JOBS FC: Spreadsheet model that that can estimate economic impacts from the manufacture & use of select types of fuel cells
  - JOBS H<sub>2</sub>: Spreadsheet model that can estimate economic impacts of select types of H<sub>2</sub> fueling stations
- DOE used these models to estimate economic impact of FC forklifts & backup power under ARRA & economic impacts of HFCVs in CA

**Minimal estimation of occupational or skill impacts**



## ASES/MISI Study

- ASES/MISI conducted comprehensive RE&EE/H<sub>2</sub> jobs study
- Forecast that widespread H<sub>2</sub> & FC market penetration could create ~ 1 million new U.S. jobs by 2030
- As many as 500K+ FC jobs & 400K+ H<sub>2</sub> jobs by 2030, depending on scenario
- Determined that jobs created are disproportionately for highly skilled, well-paid, technical & professional workers
- These provide foundation for entrepreneurship & economic growth
- Did not disaggregate H<sub>2</sub> or FC occupations or skills

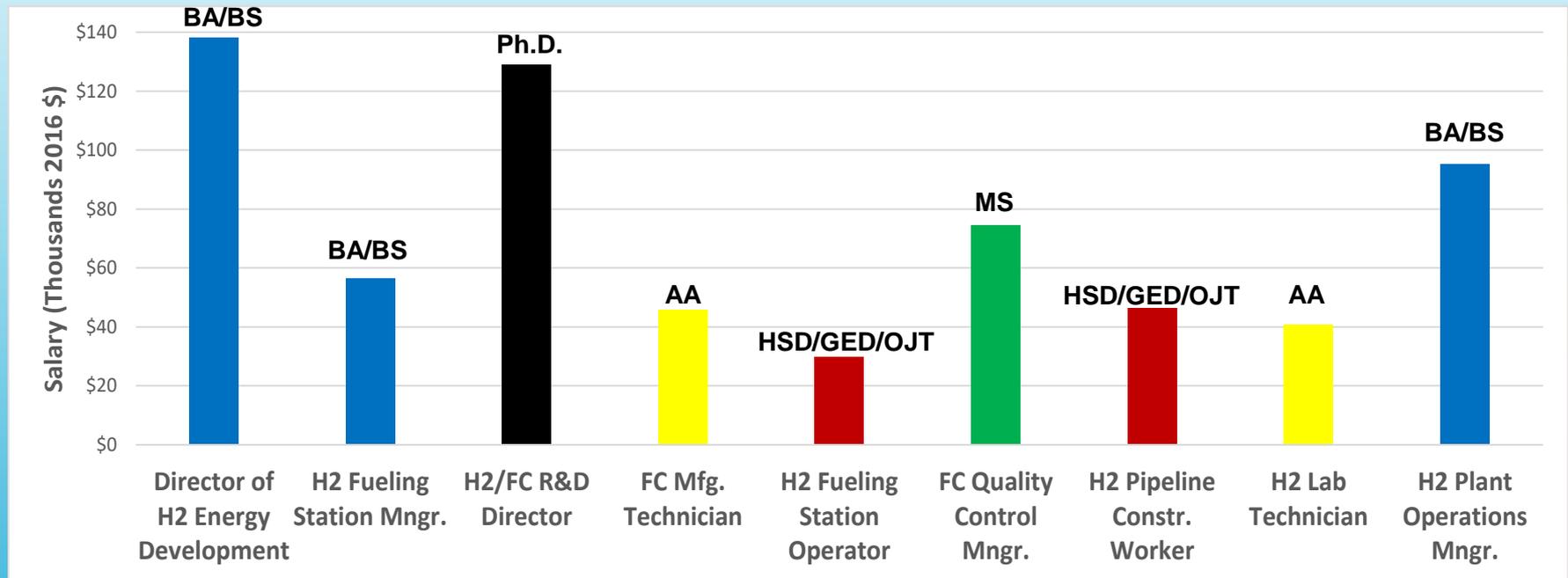


## Present Study

- Used ASES/MISI methodology & refined it
- Relate specifically to H<sub>2</sub> & FC industries, technologies, & sectors
- Disaggregated H<sub>2</sub> & FC jobs into occupations & skills
- Identified education & training requirements
- Estimated wage & salary levels -- representative average 2016 U.S. earnings
- Identified 42 emerging H<sub>2</sub> & FC occupations
- Many of these jobs do not currently exist & do not have occupational titles defined in govt. occupational handbooks & employment guides



## Examples of Emerging Jobs, Salaries, & Education & Training Requirements in H<sub>2</sub> & FC Industries



Full table included in Appendix

## Examples of Emerging Jobs, Salaries, & Education & Training Requirements in H<sub>2</sub> & FC Industries

Occupational Title	Average Salary (2016\$)	Minimum Educational Requirements
Director of hydrogen energy development	\$138,000	Bachelor's (Business)
Hydrogen fueling station manager	\$56,300	Bachelor's (CE)
Hydrogen/fuel cell R&D director	\$129,000	Doctoral
Hydrogen fuel cell system technician	\$39,500	HSD/GED/OJT/TS/apprenticeship
Junior hydrogen energy technician	\$23,400	HSD/GED/OJT/TS/apprenticeship
Fuel cell engineering intern	\$6,800	HSD/GED/OJT/apprenticeship
Fuel cell manufacturing technician	\$45,650	Associate's
Fuel cell fabrication and testing technician	\$45,800	Associate's
Hydrogen power plant installation, operations, engineering. & mgt.	\$69,700	Bachelor's (EE, ME, CE)
Hydrogen energy systems designer	\$47,900	Apprenticeship/TS
Fuel cell plant manager	\$90,500	Bachelor's (EE, ME)
Hydrogen energy system operations engineer	\$68,100	HSD/GED
Hydrogen fueling station designer & project engineer	\$74,200	Bachelor's (Engineer)
Hydrogen fuel transporter – trucker	\$36,950	OJT
Hydrogen fueling station operator	\$29,700	OJT
Hydrogen fuels policy analyst & business sales	\$56,200	Bachelor's (Business)
Hydrogen systems program manager	\$73,220	Bachelor's (Engineer)
Emissions accounting & reporting consultant	\$64,200	Bachelor's (various)

**Full table included in Appendix**

## Findings

- Salaries differ substantially: From \$20K + for various technicians, to \$140K for Director of H<sub>2</sub> Development
- Educational requirements range from apprenticeship/trade school/HSD/GED/OJT to advanced university degrees
- Numerous jobs & education/training requirements; many jobs do not require university degrees.
- Similar jobs in different parts of the industries have diverse earnings & education/training requirements.
- There exist numerous career paths that allow employees with apprenticeship/TS/HSD/GED to earn relatively high salaries
- Jobs will be created across new continuum of employment, skills, responsibilities, & earnings; many do not currently exist
- Many will require different skills than current jobs: Training needs must be determined to ensure sufficient supply of qualified employees



## Conclusions

- Growth of H<sub>2</sub> industry critically dependent on finding H<sub>2</sub> production methods that do not generate CO<sub>2</sub> emissions
- Growth in H<sub>2</sub>/FC sectors of U.S. economy will lead to vast new employment opportunities
- H<sub>2</sub> & FC industries will create numerous new high-paying jobs, many of which require technical & manufacturing skills
- States, regions, & cities can recruit these emerging industries & companies
- H<sub>2</sub> & FC industries are realistic targets for job creation in most regions and states
- With wide variety of required skills & ongoing research into H<sub>2</sub> & FC, communities can build clusters around different segments of the industries



## Recommendations

1. Accelerate R&D on H<sub>2</sub> production methods that do not generate CO<sub>2</sub> emissions
2. Forecasts of #s of new jobs created vary widely: These must be further refined to estimate # of jobs, types of jobs created, when they will occur, & where located
3. We identified 42 emerging occupations: This list must be expanded & updated as H<sub>2</sub> & FC industries mature
4. Training needed for new skills across wide spectrum of industries
5. Science & engineering education must prepare students for H<sub>2</sub> & FC careers; university & vocational programs should be modified accordingly
6. Community colleges, technical schools, colleges, & universities must prepare workforce for emerging H<sub>2</sub> & FC economy & jobs

## Appendix: Full Table

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Hydrogen systems program manager	\$73,220	Bachelor's (Engineer)
Emissions accounting & reporting consultant	\$64,200	Bachelor's (various)
Fuel cell quality control manager	\$74,600	Master's (Science/Engineering)
Hydrogen pipeline construction worker	\$46,300	HSD/GED/OJT/TS/apprenticeship
Fuel cell designer	\$78,200	Master's (Science)
Hydrogen energy engineer	\$72,300	Bachelor's (Engineer)
Fuel cell power systems engineer	\$76,400	Master's (EE)
Fuel cell fabrication technician	\$23,150	HSD/GED/OJT/TS/apprenticeship
Hydrogen systems & retrofit designer	\$90,600	Bachelor's
Fuel cell retrofit installer	\$41,600	HSD/GED/OJT/TS apprenticeship
Fuel cell retrofit manufacturer plant labor	\$36,500	HSD/GED
Hydrogen vehicle electrician	\$44,800	HSD/GED/OJT/TS apprenticeship
Fuel cell vehicle development engineer	\$69,800	Bachelor's (Engineer)
Hydrogen systems safety investigator - cause analyst	\$88,350	Bachelor's (various)
Hydrogen lab technician	\$40,600	Associate's
Hydrogen energy system installer helper	\$23,200	HSD/GED
Hazardous materials management specialist	\$55,300	Bachelor's (Science)
Hydrogen energy system installer	\$31,500	HSD/GED/OJT/TS apprenticeship
Fuel cell power systems operator and instructor	\$50,900	HSD/GED/OJT/TS apprenticeship
Fuel cell backup power system technician	\$40,200	HSD/GED/OJT/TS apprenticeship
Senior automotive fuel cell power electronics engineer	\$69,700	Bachelor's (EE)
Emissions reduction credit portfolio manager	\$47,400	Bachelor's (Business)
Emissions reduction project developer specialist	\$63,450	Bachelor's (various)
Emissions reduction project manager	\$78,600	Bachelor's (various)
Hydrogen systems sales consultant	\$53,800	Bachelor's (Business)
Hydrogen plant operations manager	\$95,200	Bachelor's (EE, ME)

Source: Cavendish Energy LLC.

## Appendix

Additional information available at <http://www.cavendish-e.com/in-the-news.html>:

- Roger H. Bezdek, “The Hydrogen Economy and Jobs of the Future,” *Renewable Energy and Environmental Sustainability*, Vol. 4, No. 1 (2019)
- Roger H. Bezdek, “Whatever Happened to the Hydrogen Economy?” *World Oil*, June 2018

[www.cavendish-e.com](http://www.cavendish-e.com)