Systems Perspectives on H2@Scale

EVOLVED
ENERGY
RESEARCH

Ryan Jones
ryan.jones@evolved.energy

November 16, 2016

Evolved Energy Research

Services

Advising

R&D Strategy

Assess the greenhouse gas reductions associated with technology deployment or incremental improvement attributable to an R&D investment. Project market-sizes and be informed about valuable technical features, lucrative technology applications, and key market opportunities.

Impact Investing

Conduct comprehensive portfolio analysis to understand the effect of portfolio holdings on energy system objectives and the risks associated with different energy system trajectories.

Technology Competitiveness

Assess technology competitiveness under a variety of energy system scenarios and find target technology price-points. Identify government policy or market developments that improve technology competitiveness.

Policy Targets

Understand the impact of a suite of policy scenarios designed to meet greenhouse gas policy targets. Compare these on economic metrics including impact on energy system costs and energy system investment.

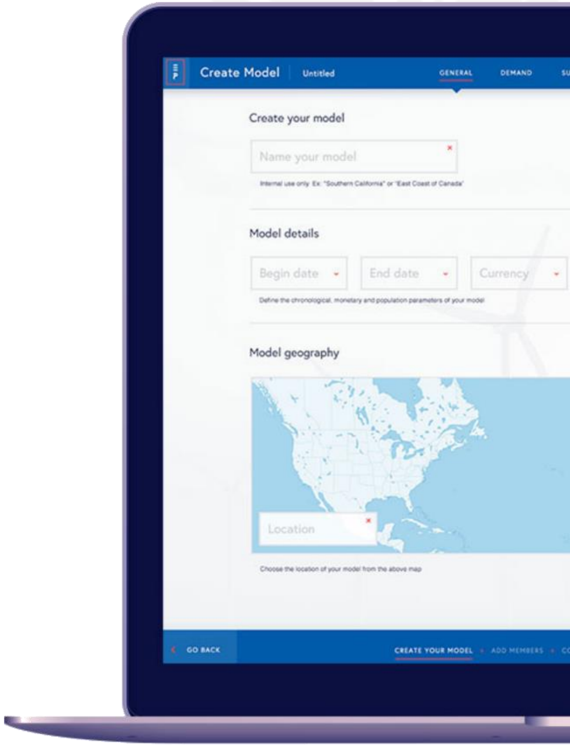
Policy Implementation

Inform sectoral benchmarking and target-setting efforts. Measure progress towards overall greenhouse gas policy targets.

Asset Valuation

Develop estimates of revenue potential under differing levels of GHG target stringency. Assess the risks of stranding for asset developers and purchases. Contextualize the role of asset categories in different scenarios to justify investment.

Training & Support



Create your model

Internal use only. Ex: "Southern California" or "East Coast of Canada"

Model details

Define the chronological, monetary and population parameters of your model

Model geography

Choose the location of your model from the above map

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

IDDRI
SciencesPo.

- Deep Decarbonization Pathways Project
  - National blueprints for limiting warming to 2°C
  - Independent research teams from 16 countries
  - 3/4 of current CO_2 emissions
  - Moving from incrementalism to transformation
  - Backcasting: how do we get there from here?

DDPP
DEEP DECARBONIZATION PATHWAYS PROJECT

2015 report

pathways to
deep decarbonization

IDDRI

deepdecarbonization.org

SCIENCE

A Path for Climate Change, Beyond Paris

By JUSTIN GILLIS DEC. 1, 2015

UN issued with roadmap on how to avoid climate catastrophe

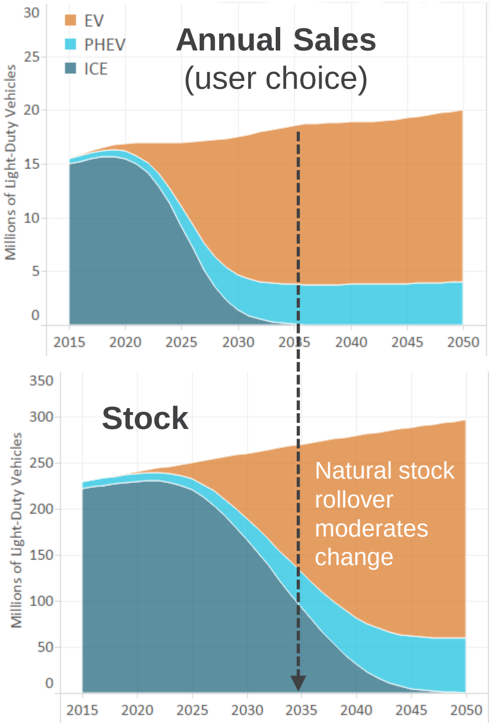
Report is the first of its kind to prescribe concrete actions that the biggest 15 economies must take to keep warming below 2C

Modeling Approach

EnergyPATHWAYS

- U.S. DDPP team has developed EnergyPATHWAYS to explore future energy systems
  - Tracks all energy infrastructure, including its energy, CO2 emissions and costs
  - Estimates energy demand from the “bottom-up”
    - Exogenous activities (ex., population and floorspace)
    - Equipment efficiencies
  - Simulates power system operations though hourly electricity dispatch
- Deep decarbonization pathways cases include user-defined measures which change the composition of new energy infrastructure
  - See light-duty vehicle example

Light-Duty Vehicle Fleet
(Illustrative Example)



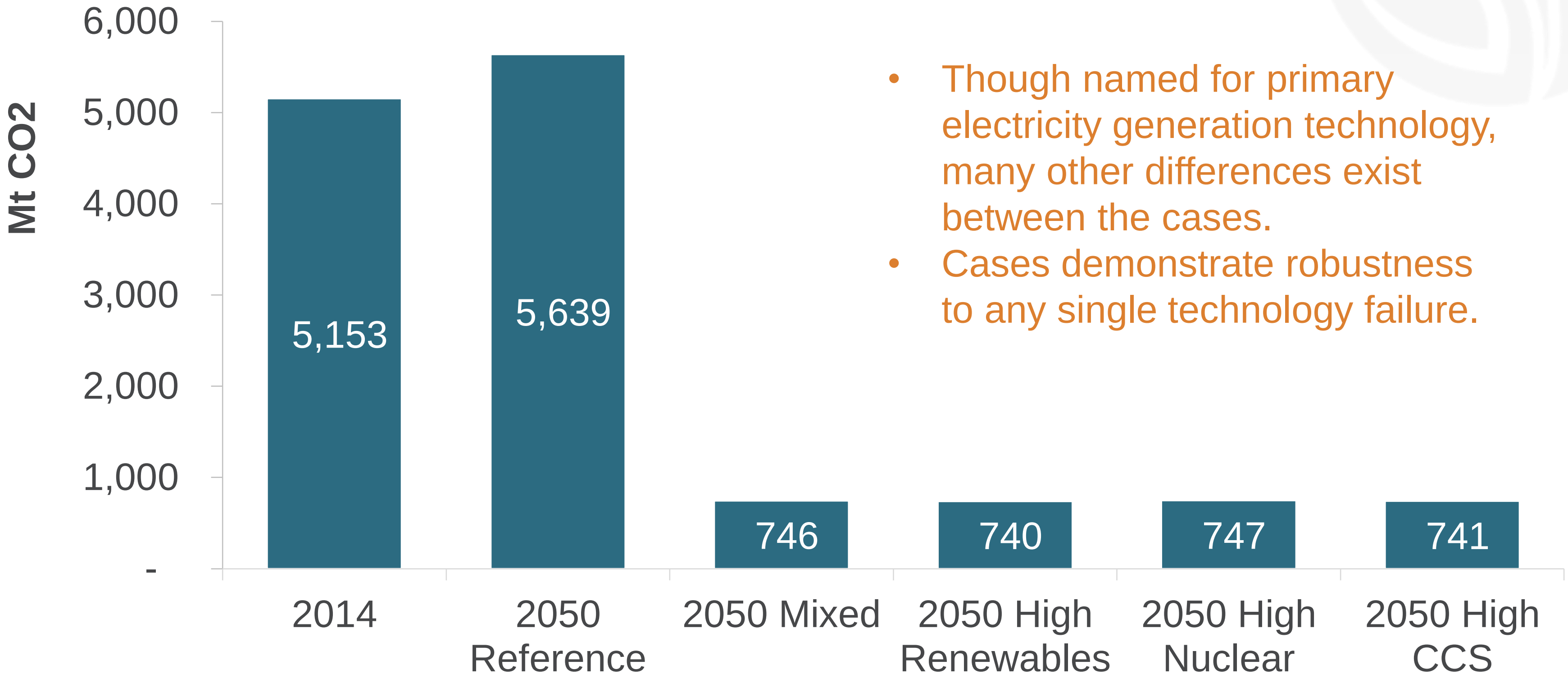
Key case assumptions

- Table below details a number of design principles applied to pathways analyses:

Design Principle	Implication
Economy and lifestyle similar to that of today	• Same level of energy services demand across cases • For example, no decrease in vehicle miles traveled
Use commercially demonstrated or near-commercial technologies	• No major breakthrough technologies, such as nuclear fusion, to save the day
Infrastructure inertia	• Natural retirement of infrastructure • No early retirements
Electric reliability	• Ensure resource adequacy and flexibility
Environmental limits	• Reasonable sustainability limits on biomass use and hydropower

Key finding: multiple feasible technology pathways exist

Four scenarios that reach per capita energy emissions of 1.7 t/person



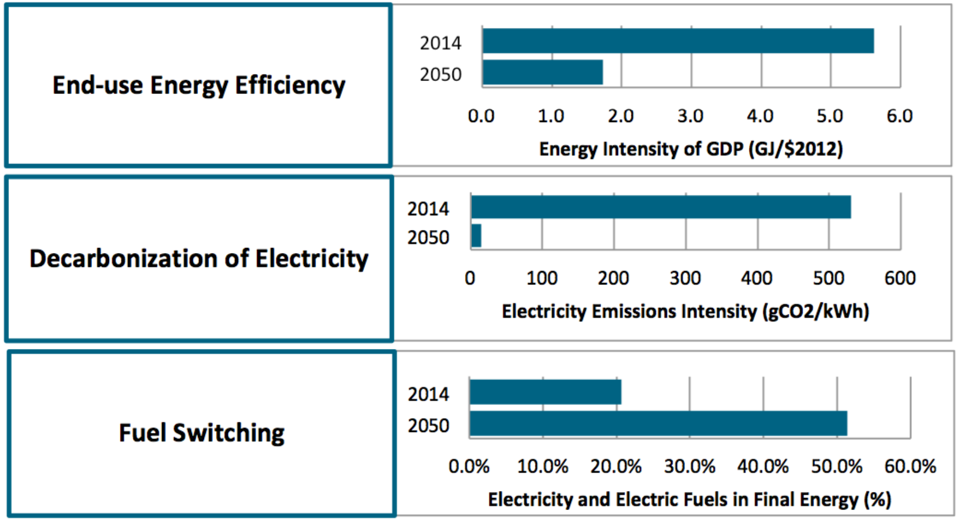
- Though named for primary electricity generation technology, many other differences exist between the cases.
- Cases demonstrate robustness to any single technology failure.

Three pillars of deep decarbonization

Findings are robust across all 16 DDPP country teams

2050 U.S. Benchmarks

- 3x drop in energy use per unit GDP
- 30x reduction in emissions intensity of electricity
- 2.5x increase in the share of energy from electricity or electrically derived fuels



Motivation for H2@Scale

Why is the concept of H2@Scale intriguing from a deep decarbonization perspective?

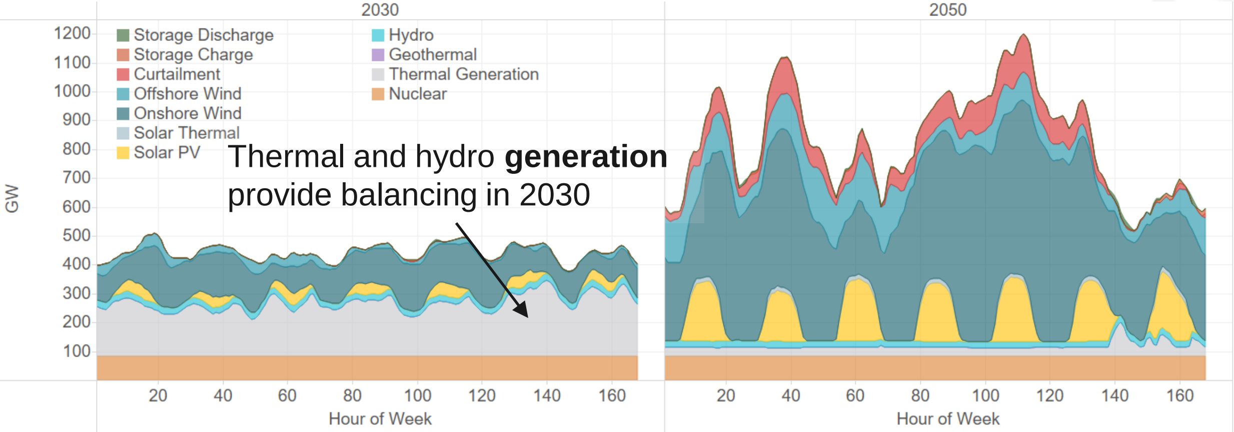
1. Hydrogen and power-to-gas are the lowest cost long duration balancing solutions in electricity systems with inflexible supply.
2. Fuel switching of end-use fossil fuel combustion is necessary for deep decarbonization and certain applications are not well served by direct use of electricity or by battery storage.
3. Hydrogen already plays an important (and potentially expanding) role in industry and near-zero carbon hydrogen is needed to meet existing demand.

Photo credits: Uniper Energy Storage GmbH

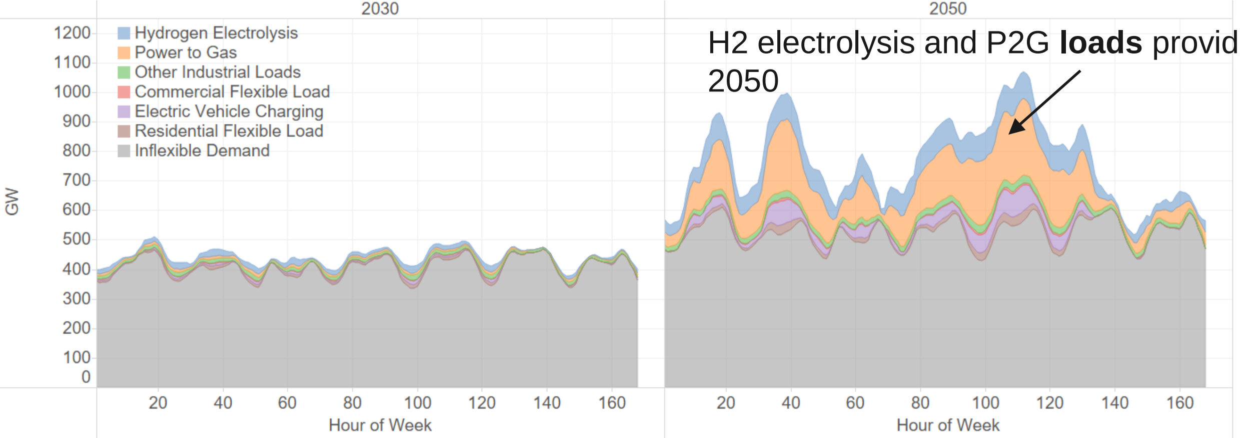
Falkenhagen, Germany (2013)

Source: http://www.hydrogendays.cz/2016/admin/scripts/source/presentations/PL%2005_%20Denis%20Thomas_HDs2016.pdf

Eastern Interconnection, High Renewables

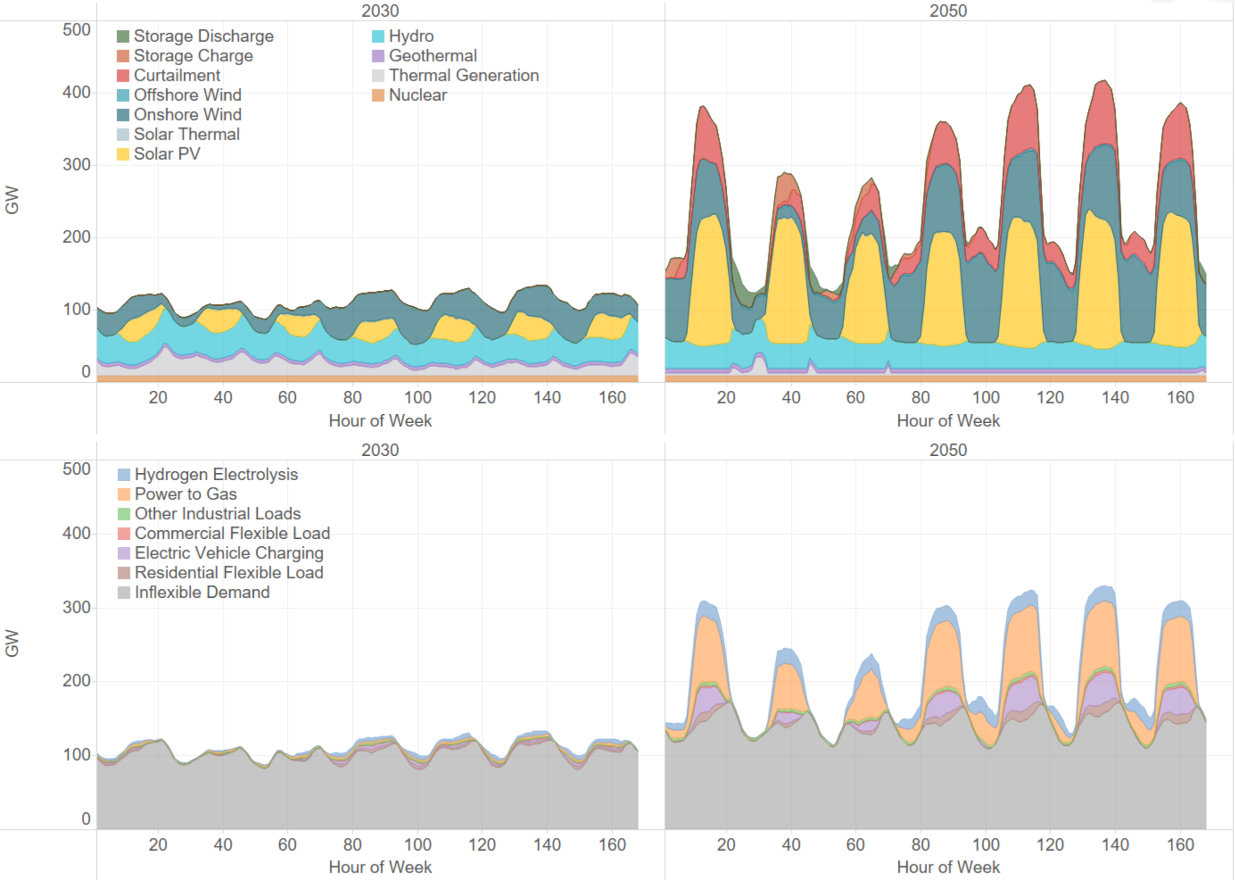


Thermal and hydro **generation** provide balancing in 2030



H2 electrolysis and P2G **loads** provide balancing in 2050

Western Interconnection, High Renewables

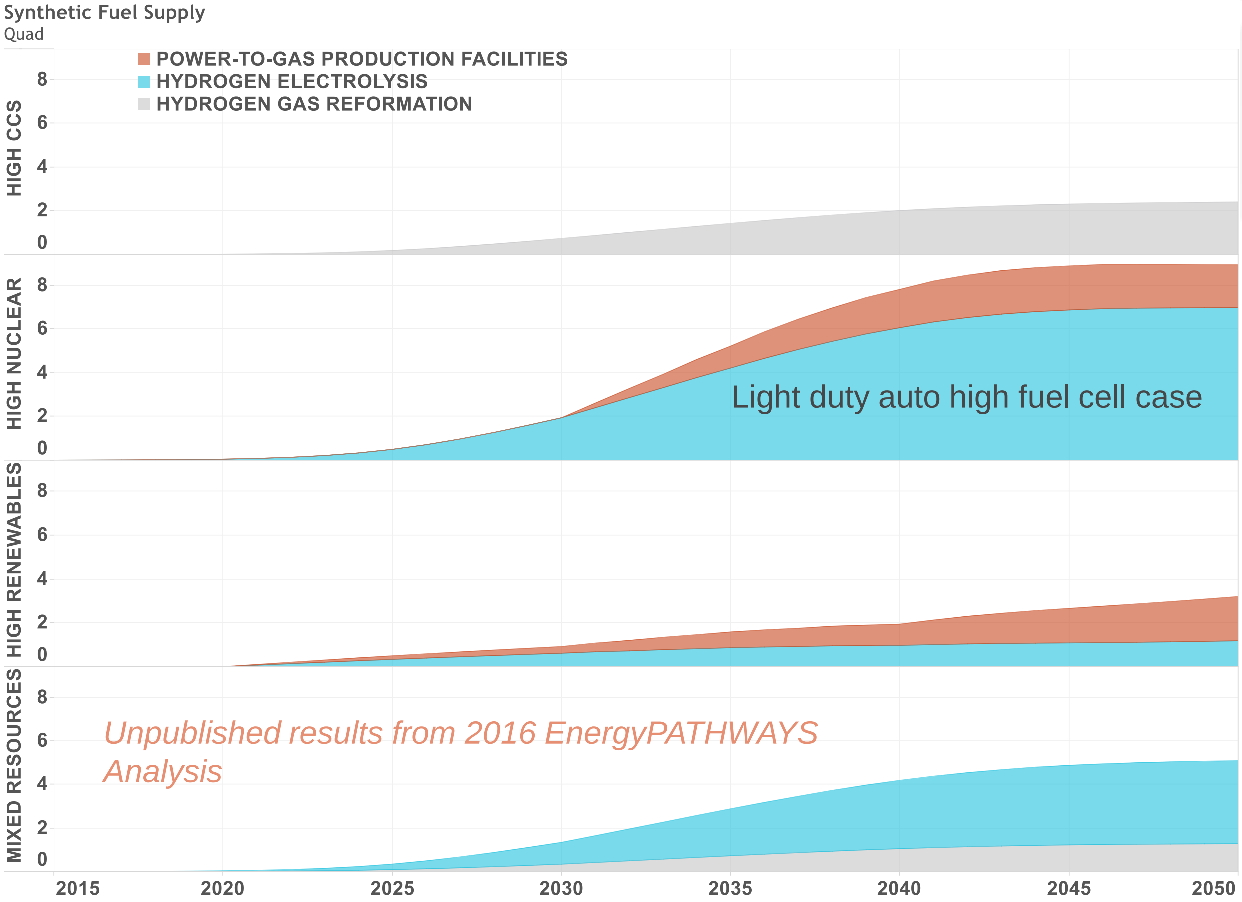


Synthetic fuel production in the U.S. DDPP cases

H2 at Scale Analysis Team projects potential hydrogen demand of 7.9 Quads in 2050

Slide 14

https://www.hydrogen.energy.gov/pdfs/htac_apr16_10_pivovar.pdf



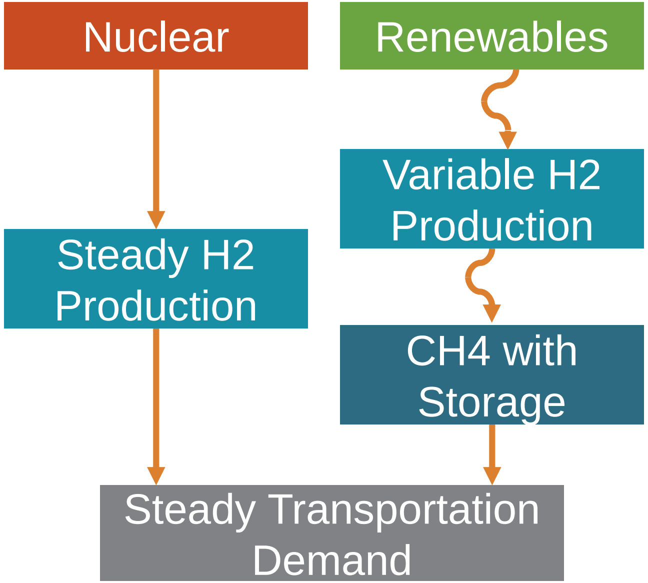
Light duty auto high fuel cell case

Unpublished results from 2016 EnergyPATHWAYS Analysis

Electricity Consumption Share

Unpublished results from 2016 EnergyPATHWAYS Analysis

For transportation applications, nuclear & H2 are naturally complementary, as are renewables & CH4



Nuclear

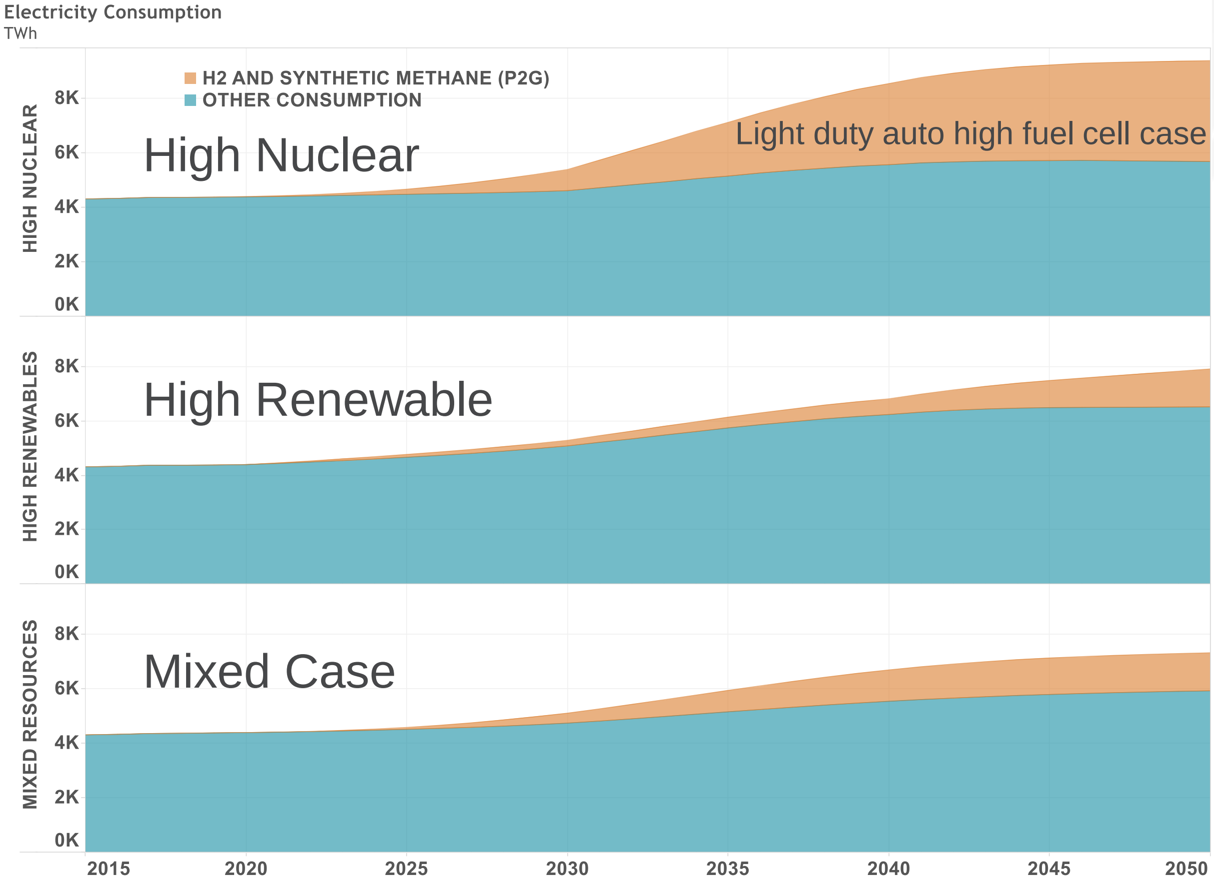
Renewables

Variable H2 Production

Steady H2 Production

CH4 with Storage

Steady Transportation Demand



Choosing a hydrogen production method in a very low GHG context

Arrows indicate the degree of synergy between electricity generation and H2 production

		Hydrogen production	
Electricity generation	Electrolysis [1]	High Temperature [2]	SMR or POX with CCS [3]
Renewables	⬆ Provides long duration balancing and allows distributed production	➡ Provides some balancing, but wind and PV are excluded and production is centralized	⬇ No balancing for renewables
Nuclear	⬆ Provides balancing and locational production flexibility	⬆ Provides balancing, but centralized so transportation becomes critical	No notable synergies
Fossil w CCS	⬇ Balancing not needed and SMR or POX with CCS would be preferred	⬇ SMR or POX with CCS would preferred	➡ Doing CCS for both requires very high capture rates to meet GHG targets

[1] Alkaline water electrolysis or PEM electrolysis
[2] High temperature electrolysis or thermolysis
[3] Steam reforming or partial oxidation

Additional perspectives on H2

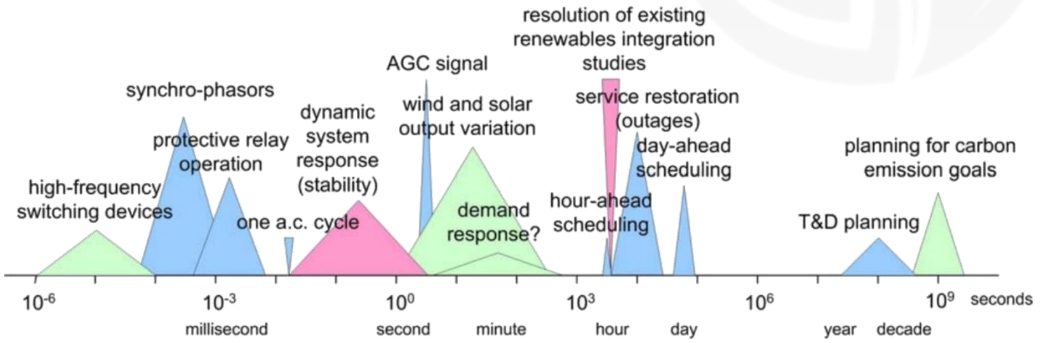
- Net energy system cost, not $/kg, is the important metric for H2@scale
  - As an enabling technology, public policy must be made from a systems perspective
- In the long term, H2 production is non-marginal in electricity systems, meaning electrolysis units are not market price takers and can’t rely on ‘free’ overgen
- Electrolysis in a high renewables or high nuclear system systems will have low capacity factors (<50% in U.S. DDPP cases)
  - Lower capital cost becomes more important than conversion efficiency
- Most stationary power generation in a high renewables or high nuclear case will also have low capacity factors
  - Capacity factors <10% for remaining dispatchable generation mean that stationary fuel cells need to compete economically to provide capacity, not energy

Building to H2@Scale

When, how, and why policy makers should think about H2

- Balancing solutions for a longer time-scale often solve shorter timescale problems
    - E.g. electrolysis can be used for frequency regulation, but flywheels cannot be used for seasonal energy storage
- **Early deployment of long-duration balancing solutions**, like hydrogen, **will lead to a lower cost system** by avoiding the double deployment of technologies that address short-duration balancing
    - Industry or pipeline gas blending are two early applications

Figure 1: Time Scales for Power System Planning and Operation



10% RPS

30% RPS

80% RPS

As non-dispatchable generation levels increase, the timescale of energy imbalance gets progressively longer

Graphic from Alexandra Von Meier
http://uc-ciee.org/downloads/CEC-500-2014-042.pdf

THANK YOU

📍 2443 Fillmore Street, No. 380-5034
San Francisco, CA, 94115

☎ (415) 580-1804

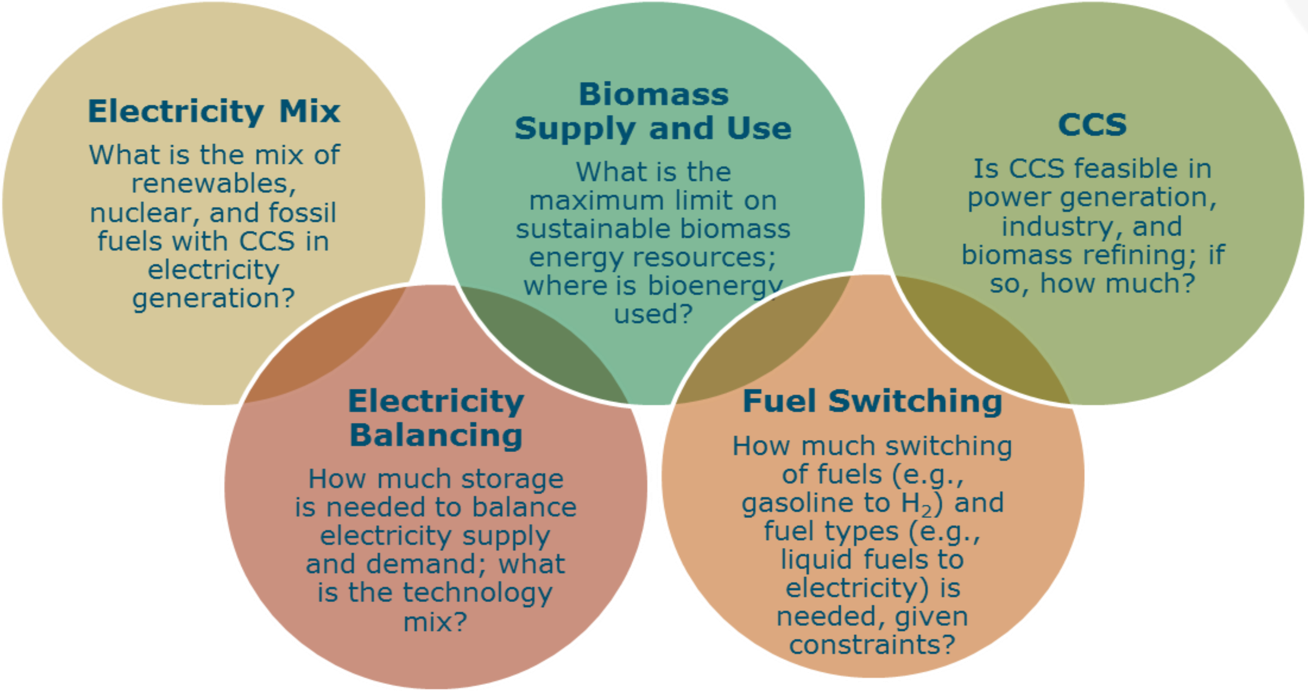
✉ info@evolved.energy

🌐 www.evolved.energy

EVOLVED
ENERGY
RESEARCH

5 Key Elements of Low Carbon Energy Systems

Interrelated components of good system design



Electricity Mix

What is the mix of renewables, nuclear, and fossil fuels with CCS in electricity generation?

Biomass Supply and Use

What is the maximum limit on sustainable biomass energy resources; where is bioenergy used?

CCS

Is CCS feasible in power generation, industry, and biomass refining; if so, how much?

Electricity Balancing

How much storage is needed to balance electricity supply and demand; what is the technology mix?

Fuel Switching

How much switching of fuels (e.g., gasoline to H_2) and fuel types (e.g., liquid fuels to electricity) is needed, given constraints?

www.USDDPP.org