UCDAVIS

SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

An Institute of Transportation Studies Program

Alternative Fuel Infrastructure Challenges and Opportunities

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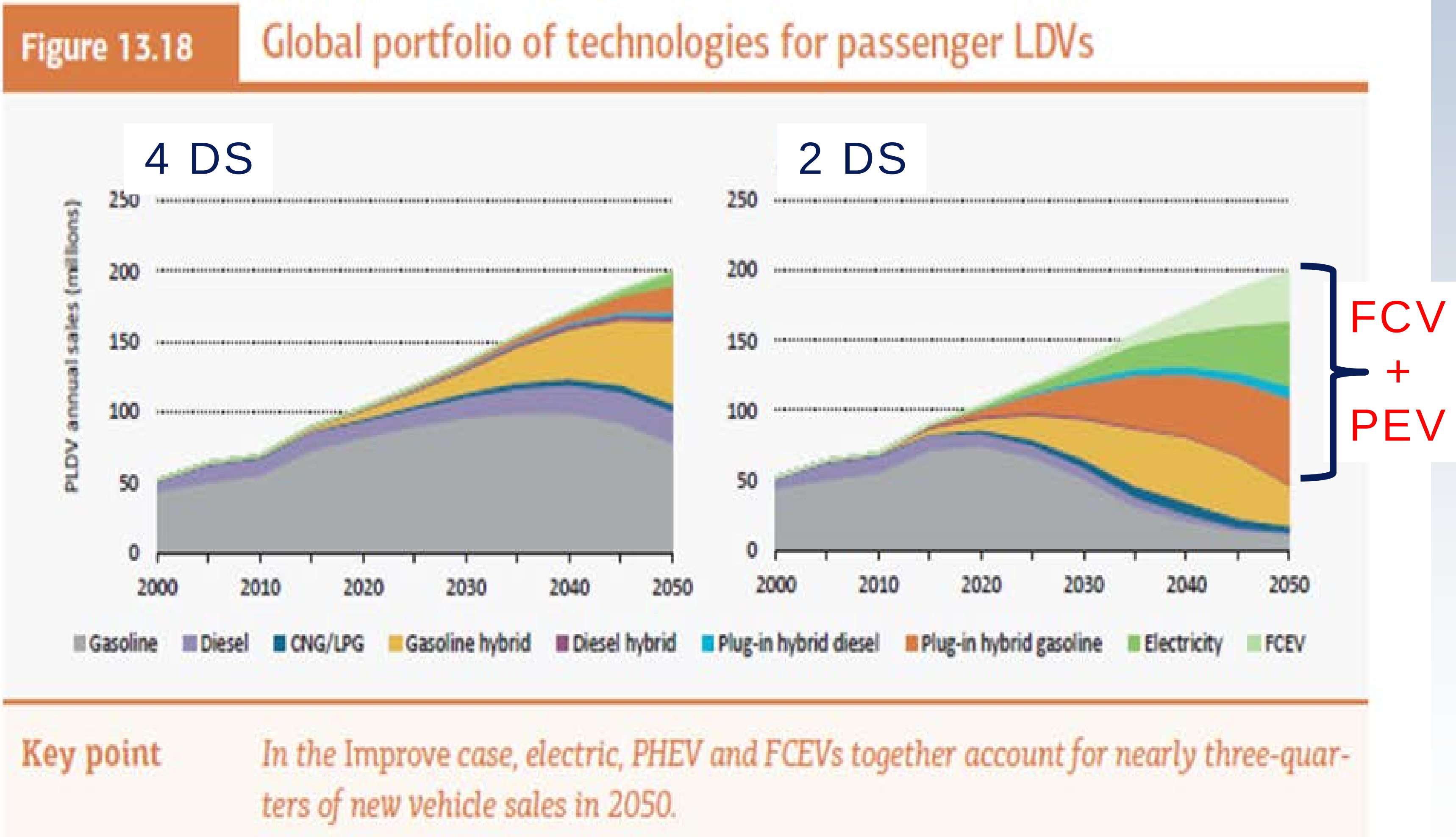
Presented at Asilomar

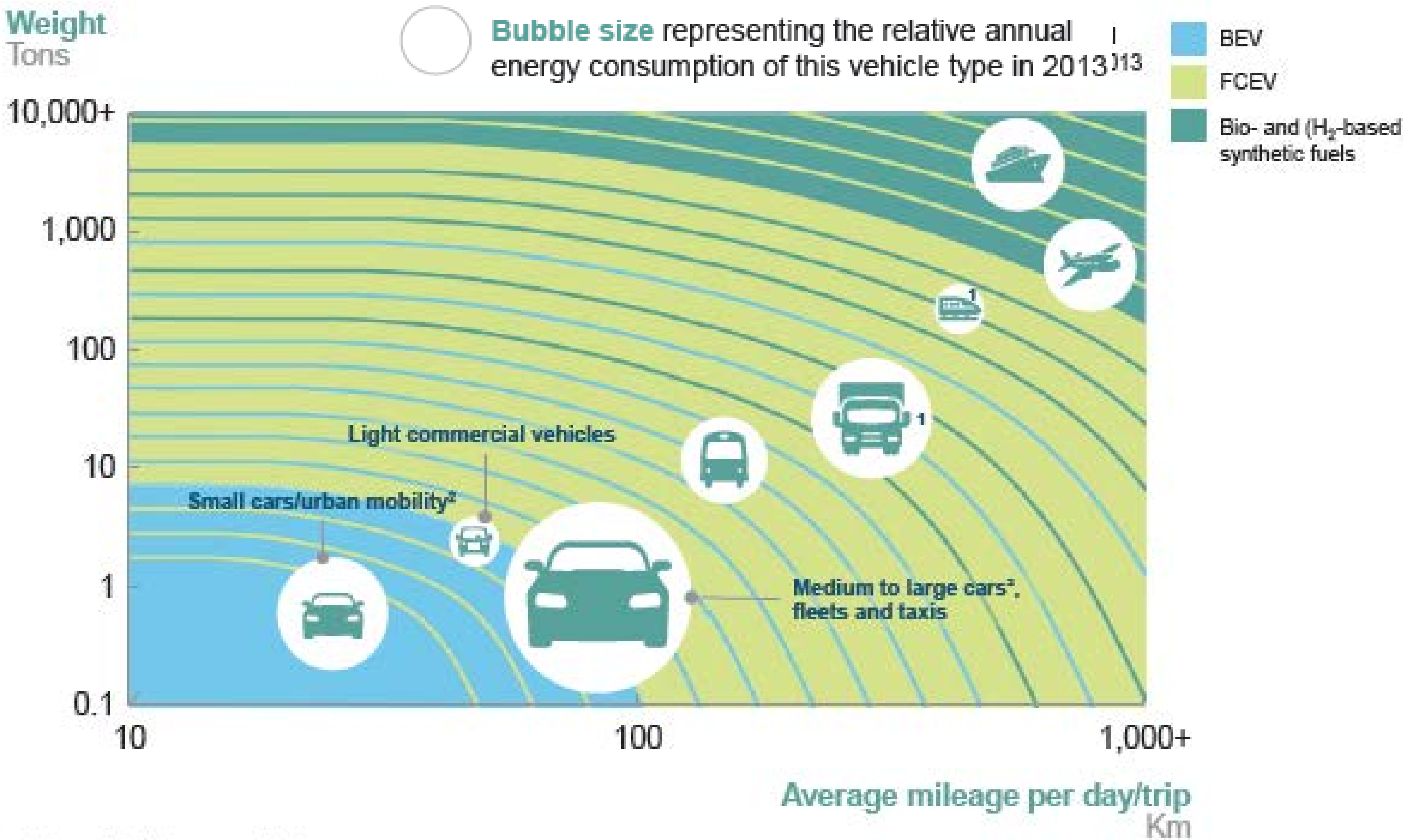
August 24, 2017

Integrated Assessment Modeling =>
Elec. Drive, Low-C Fuels Play Major Role in 2º Scenario



Source: International Energy Agency Energy Technology Perspectives 2012

Transport Sector Portfolio: BEVs, H_2 FCVs, Synfuels



1 Battery-hydrogen hybrid to ensure sufficient power
2 Split in A- and B-segment LDVs (small cars) and C+-segment LDVs (medium to large cars) based on a 30% market share of A/B-segment cars and a 50% less energy demand

Source: Hydrogen Council, How hydrogen empowers the energy transition, January 2017. http://hydrogeneurope.eu/wp-content/uploads/2017/01/20170109-HYDROGEN-COUNCIL-Vision-document-FINAL-HR.pdf

Infrastructure Implications

TRANSPORTATION TAPS INTO EVOLVING ELECTRIC GRID *(w/**increasing % variable renewable power)***

- EV charging, power-to-gas, power-to-liquids

NEW FUELS =>

- Adapt/use existing infrastructure.
  (Drop-in biofuels? Blend H2 w/ NG? Smart elec. grid)
- New dedicated infrastructures

NEW INFRASTRUCTURE FOR CARBON MANAGEMENT

- Carbon Capture (Chemical Process or Atmospheric)
- CCS (pipelines and storage)

Tapping into the Electric Grid
Renewable “Power to Gas”

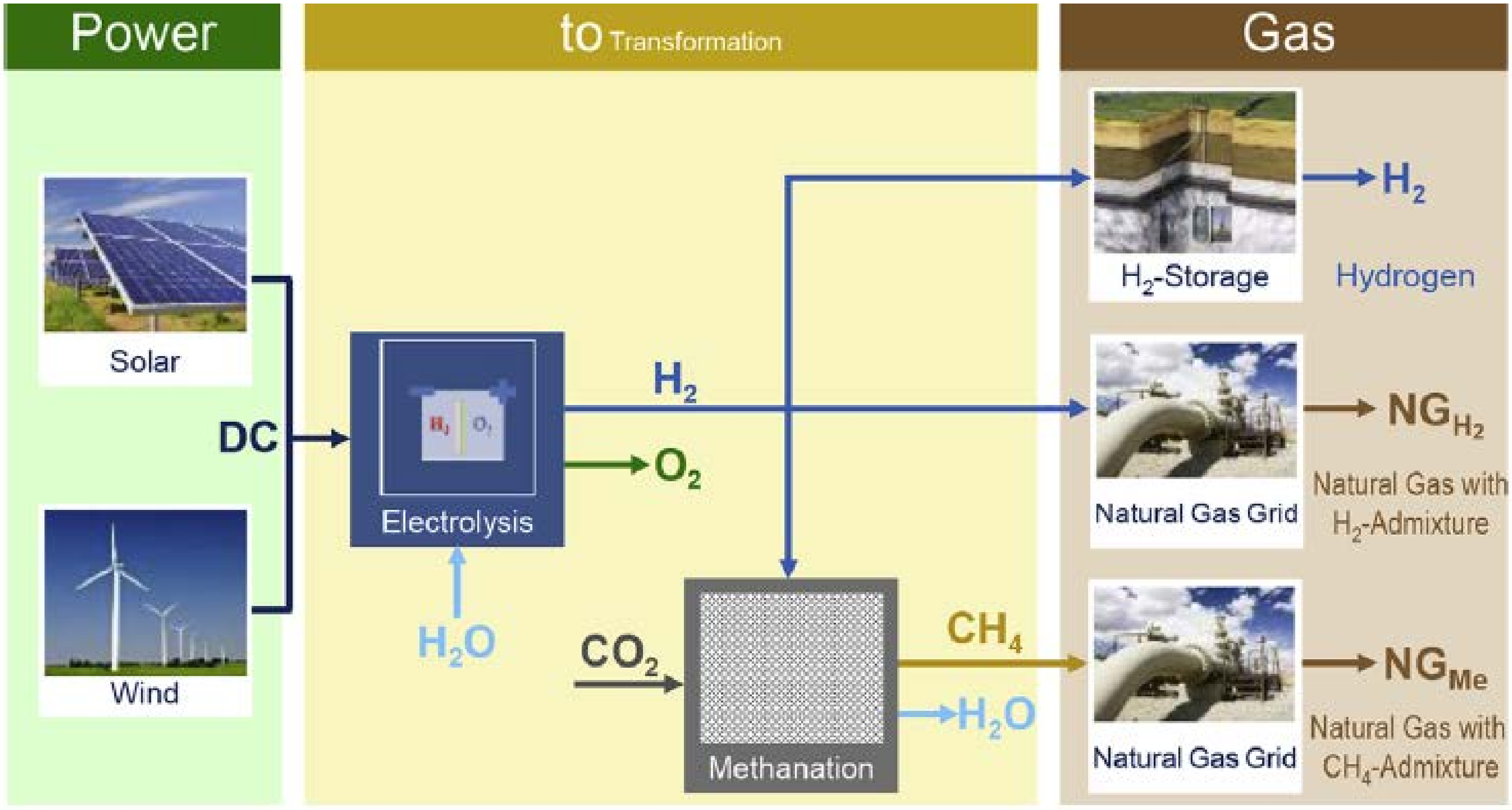


Fig. 1 – Principle of power-to-gas concept [5].

Schiebahn, S., Grube, T., Robinius, M., Tietze, V., Kumar, B., Stolten, D., 2015. Power to gas: Technological overview, systems analysis and economic assessment for a case study in Germany. International Journal of Hydrogen Energy, 40, 4285–4294. http://www.sciencedirect.com/science/article/pii/S0360319915001913. Accessed July 10, 2017.

Can we re-use existing infrastructure w/ new fuels?
Blending H2 into NG Grid

FEASIBILITY:

•Technically possible to blend 5-15% H2 (by vol.) into NG; requires careful case by case assessment of NG network.

•For major GHG reductions, need H2 separation&use in hi-eff FCVs.

Near to Mid Term:

•Make electrolytic H2 from excess renewable power, blend w/NG, separate and use in FCVs.

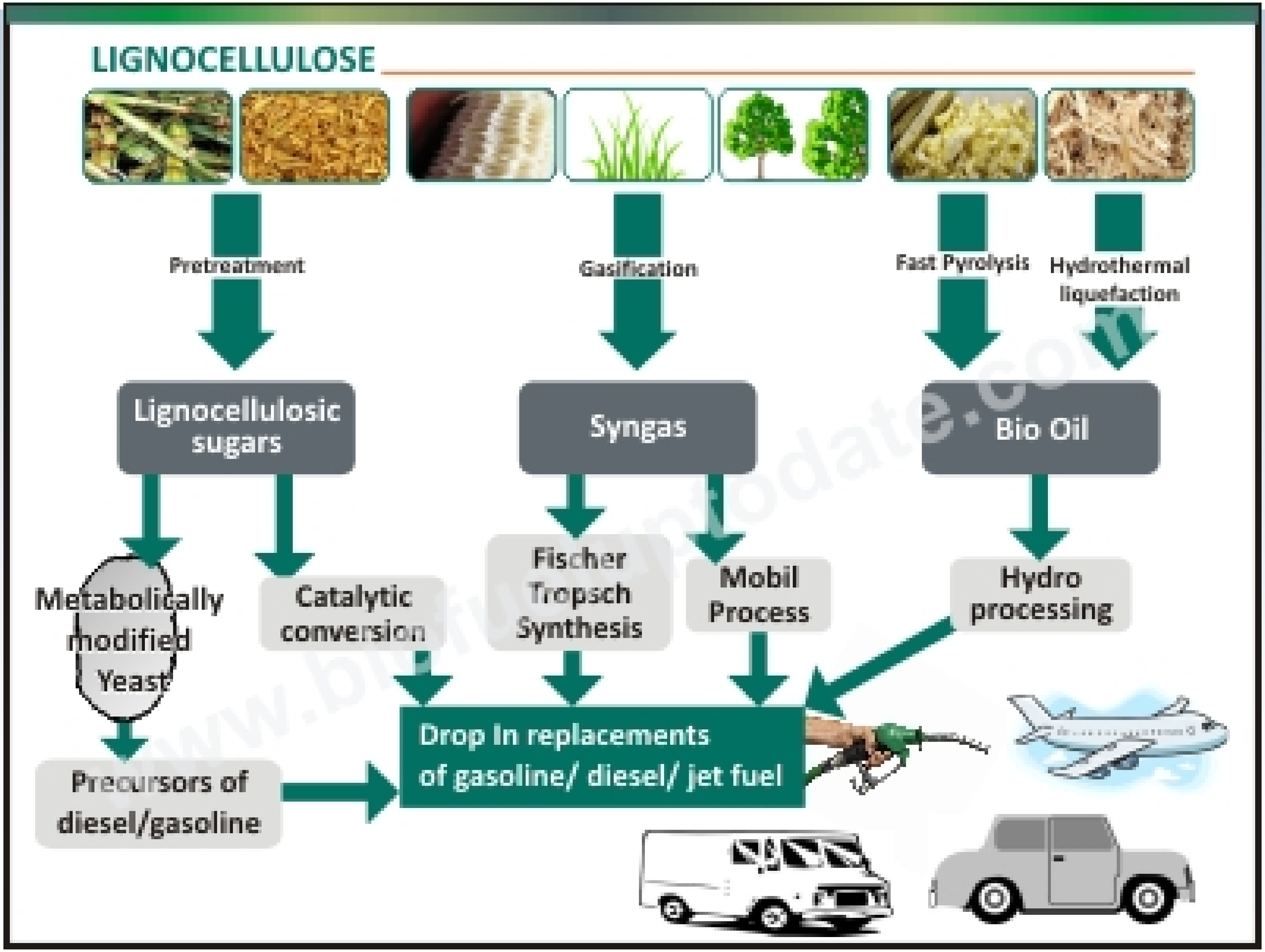
Long Term:

•Blend limits => difficult for existing NG system to deliver enough green H2 to enable deep cuts in transportation related GHGs.

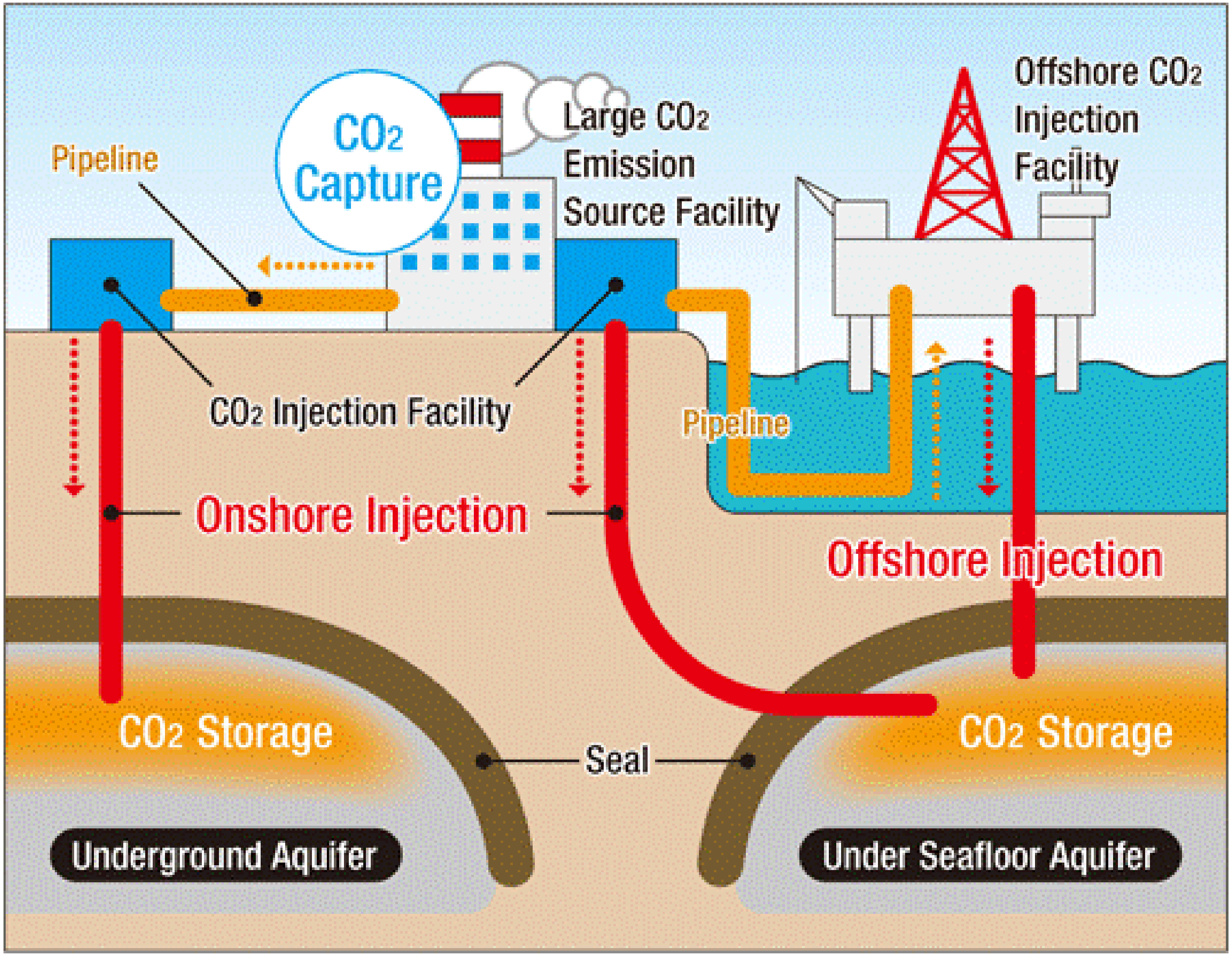
•In 2º world, demand for H2 transportation fuel might far exceed ability of NG system to deliver H2 as part of a blend.

•In Long-term, dedicated, low-C H2 infrastructure needed.

Can we re-use existing infrastructure w/ new fuels? Drop-in Biofuels



New Infrastructure for Carbon Management
CO2 capture and Sequestration



THREE COUPLED TRANSITIONS

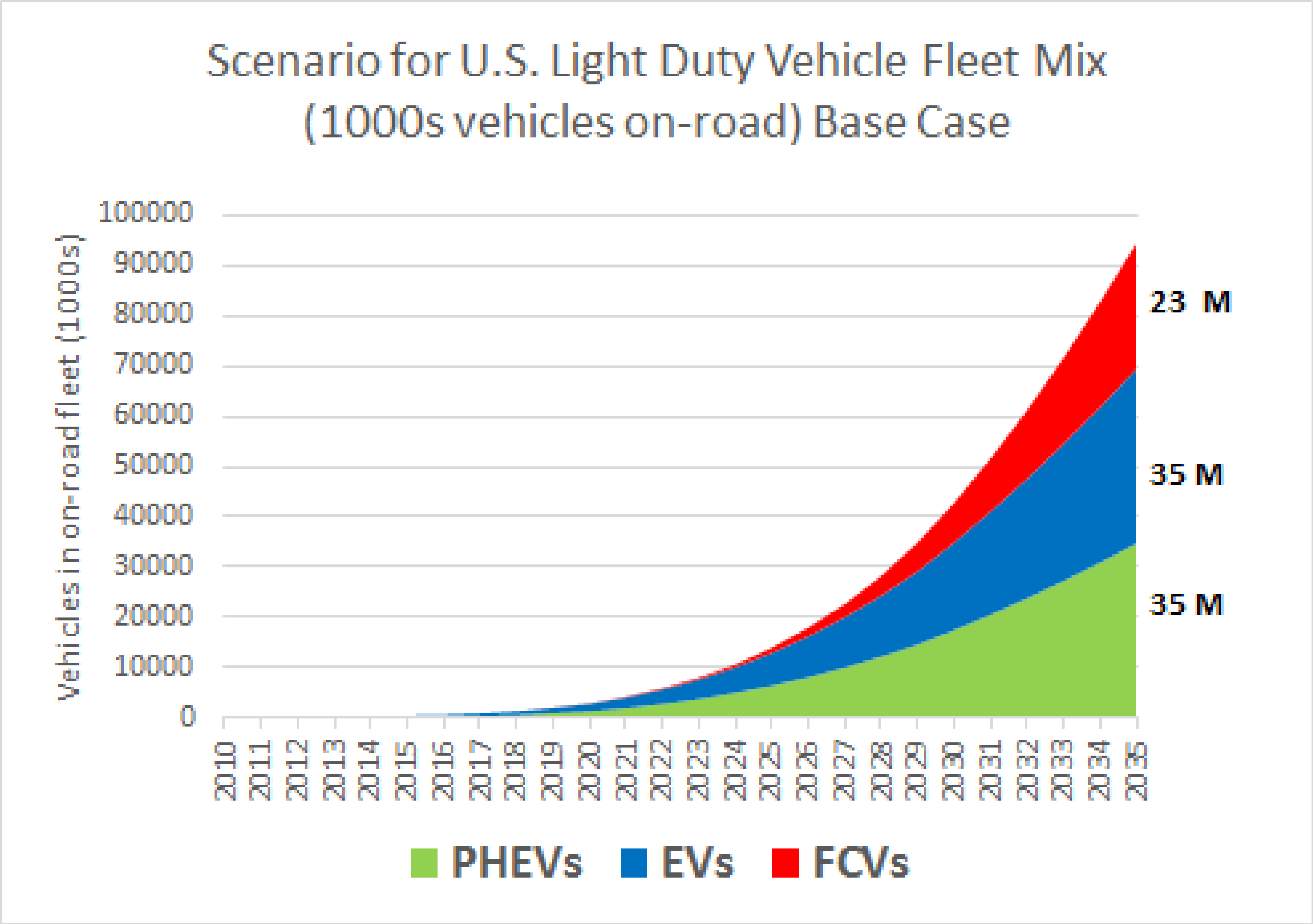
- New types of vehicles
- New fuel infrastructures
- Shift to zero net carbon fuel supply pathways

Historically Energy Transitions Take Decades

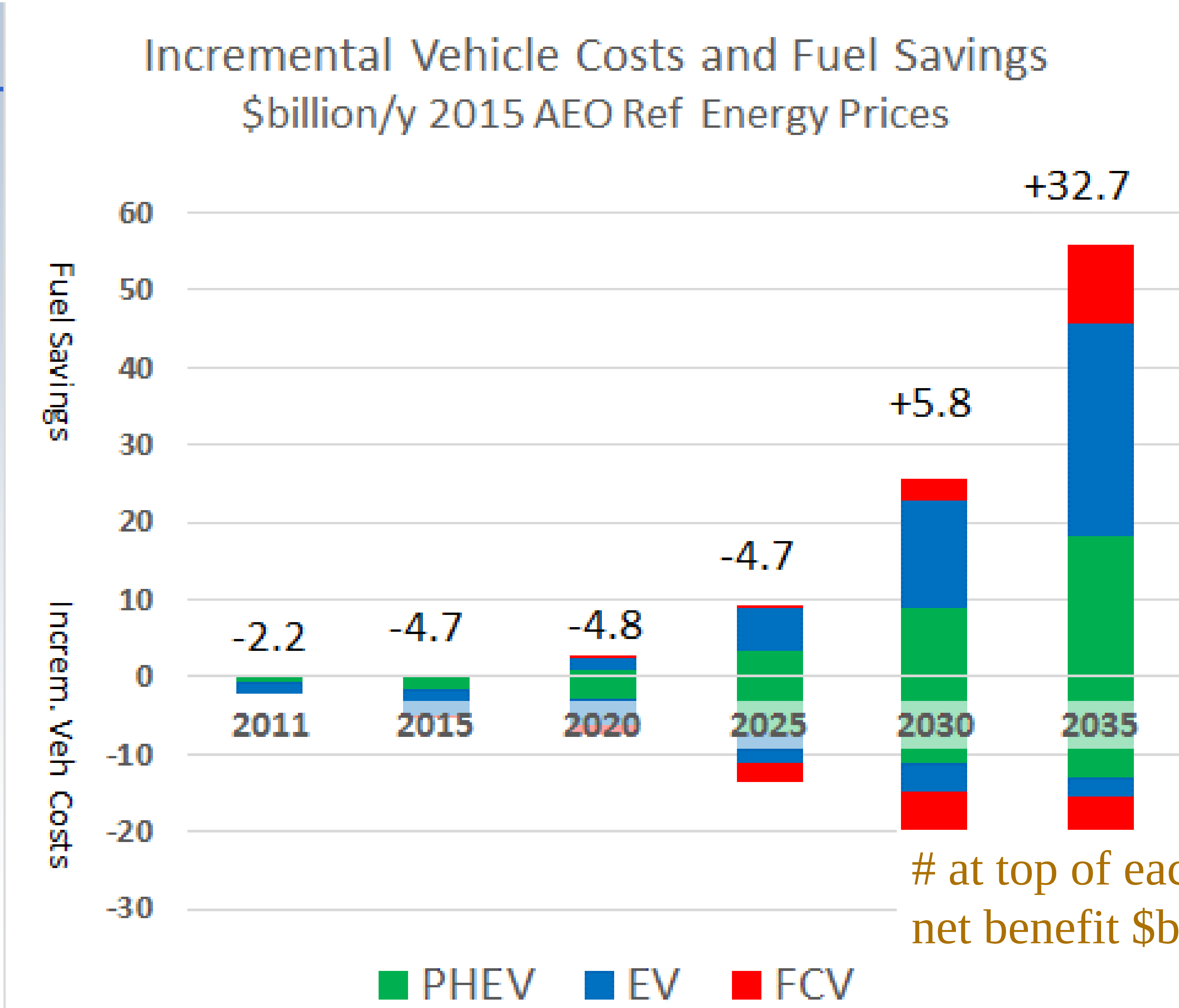
Factors Affecting Rate of Change (Grubler 2012)

- **Scale or market size**. More difficult to transform a large market than a small system.
  - Transitions begin on small local scales, evolve into nationwide developments, then become truly global phenomena
- **Infrastructure needs.** The more complex the infrastructure, the slower the change.
- **Uncertainty** about policy and technology can lead to risk averse behavior.
- **Changing patterns of mobility, vehicle ownership**

TRANSITION SCENARIO: US ZEV LIGHT DUTY VEHICLES

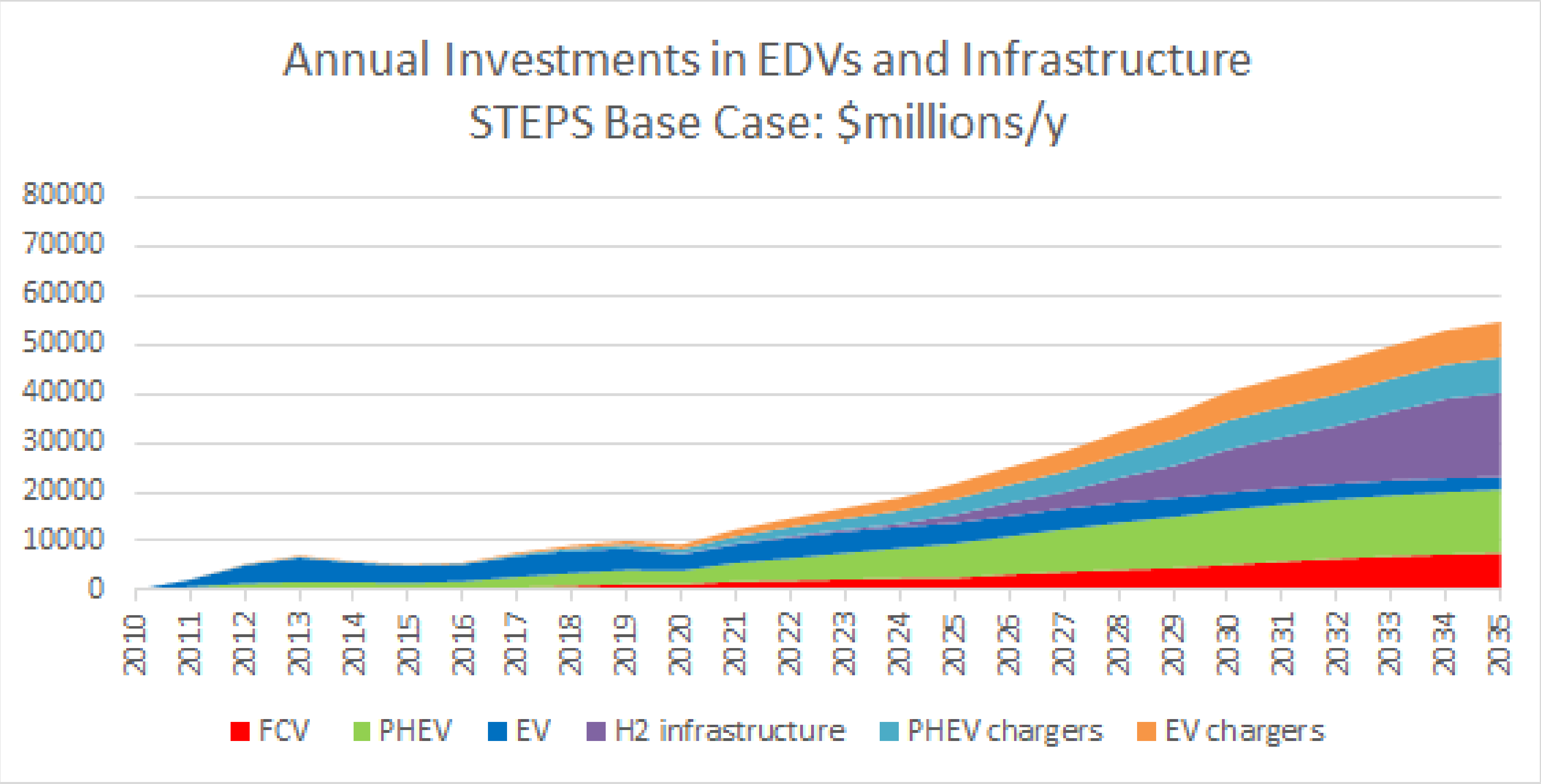


US ZEV LDV TRANSITION SCENARIO Net benefit >0, c. 2028

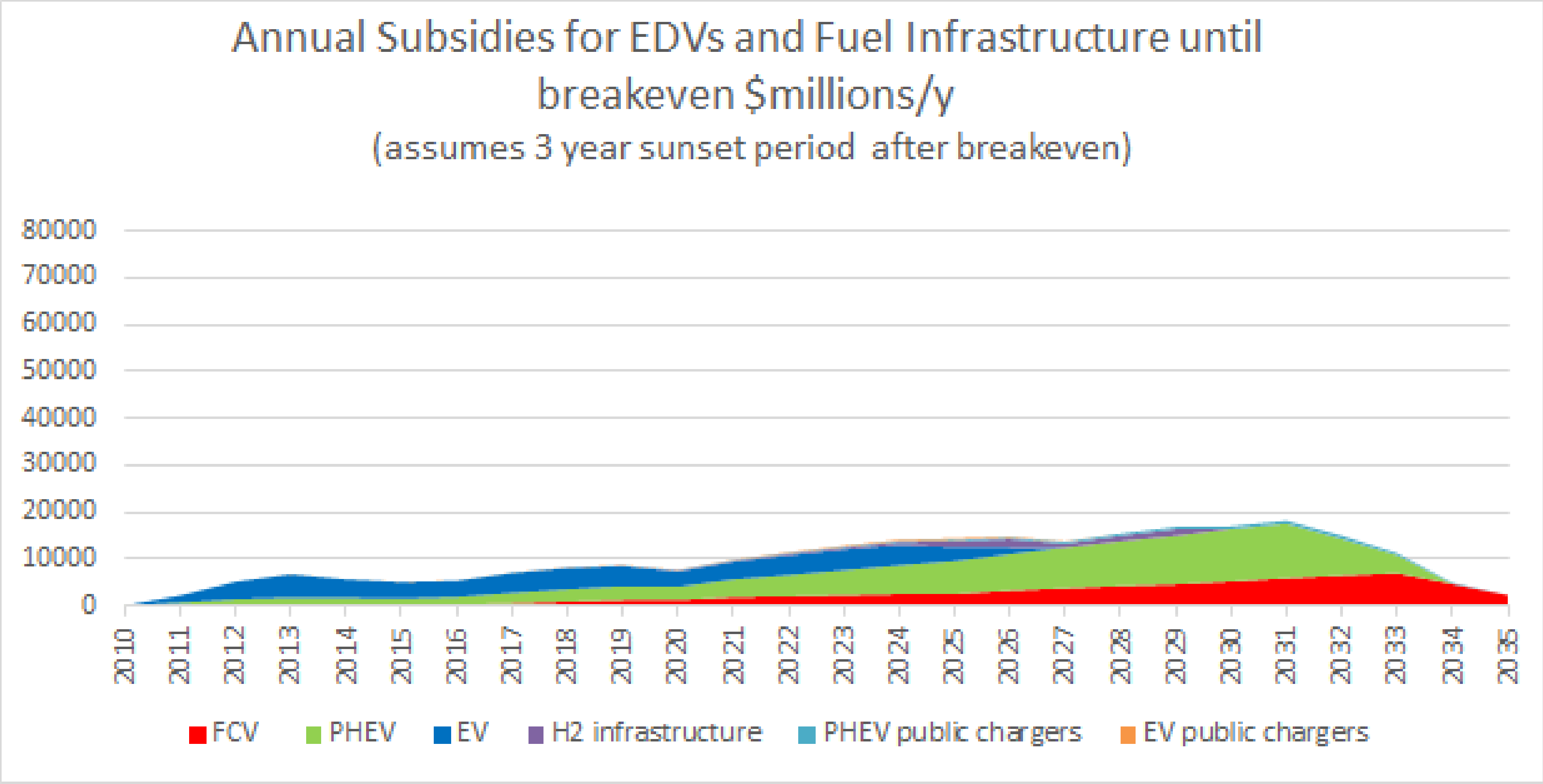


at top of each bar is net benefit $billion/y

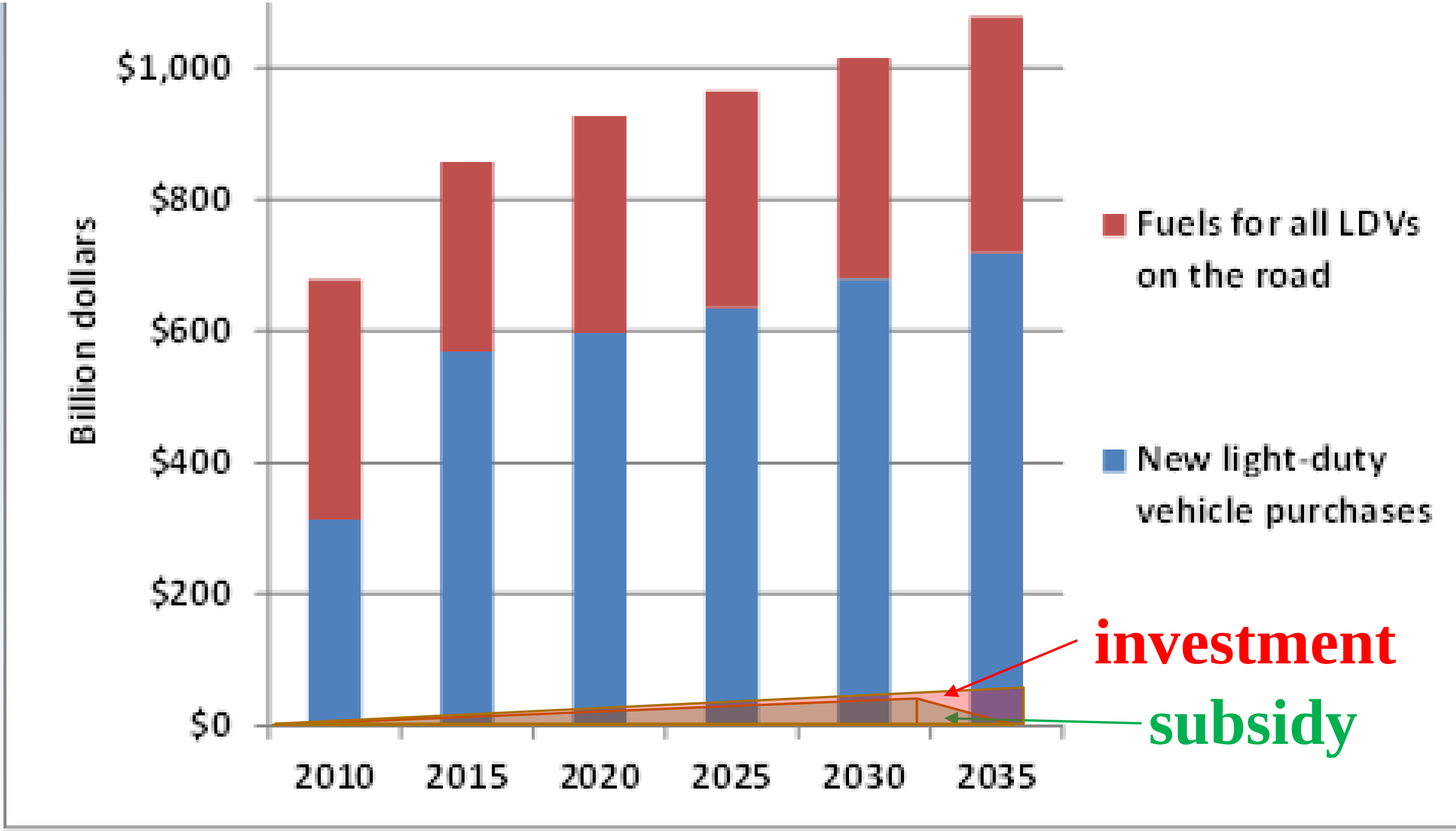
Incremental INVESTMENTS for Alt Fueled Vehicles and Infrastructure ($M/y) Ave ~$23 B/y



SUBSIDIES for ZEVS and Infrastructure w/ 3-yr phase out after Breakeven ($M/y) Ave ~$11 B/y



HOW DO TRANSITION COSTS COMPARE?
US estimate: $19 trillion on new cars & fuels to 2035



Cum. ZEV subsides & investment costs <1-3% of total;
Subsidy phase out ~2035

Guidelines for Infrastructure Transition

Portfolio of transport fuels in future low C world. Keep range of options open.

Policy alignment, continuity over many decades.

System level learning: City/regional scale rollouts of infrastructure & vehicles;decarbonize primary energy

Keep costs in perspective:
R&D << System level demo<<$ flow in energy system

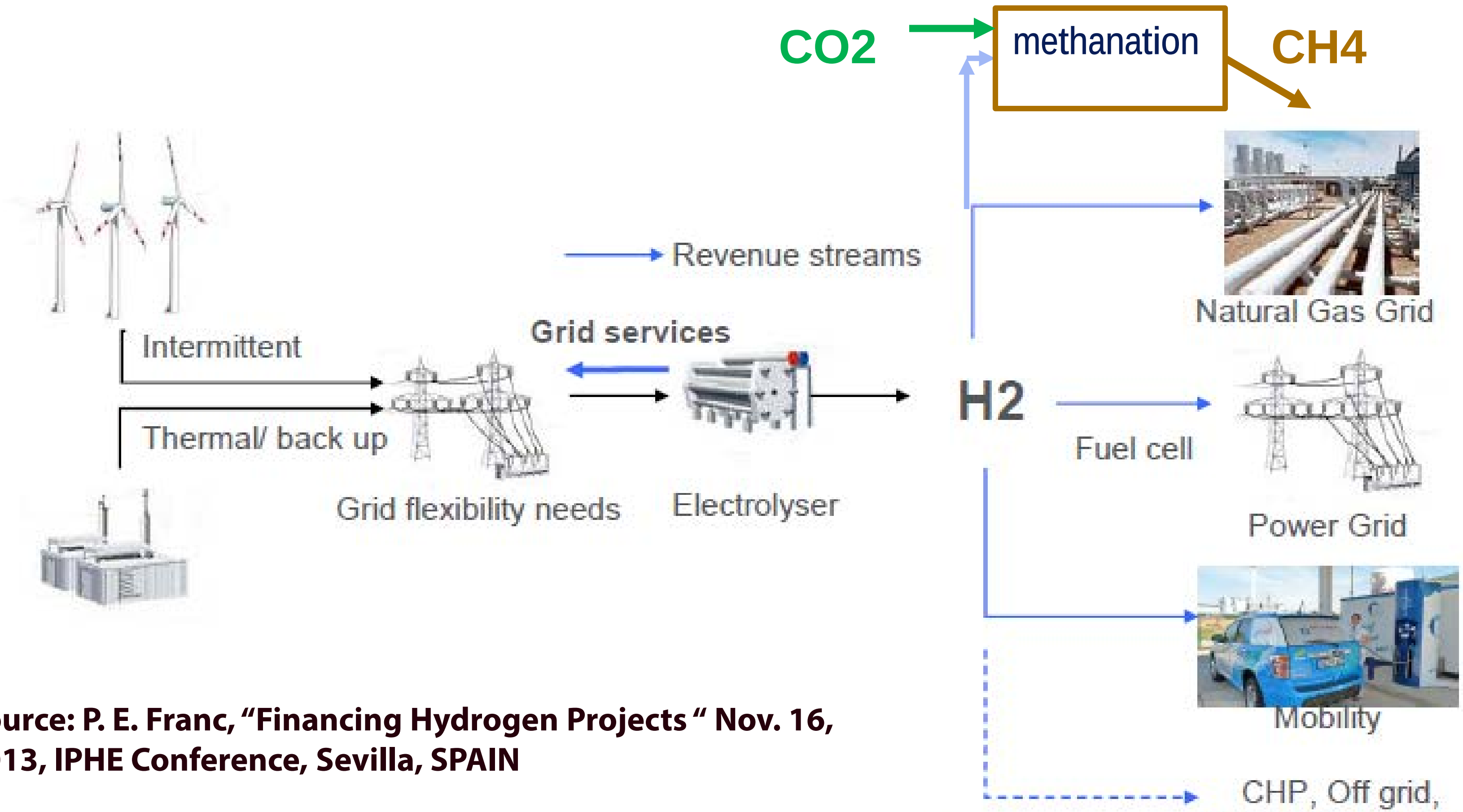
Given urgency of climate change, need to explore several transport fuel options in parallel.

extras

SUMMARY: Key points of talk

- Efficiency, electrification, low C fuels characterize transport in 2 degree scenario (2 DS)
- 2 DS => coupled transitions to:
  new types of vehicles/new fuels/ decarbonized primary supply
- 2 DS => major fuel infrastructure changes: Re-use existing infra (hi-renewable elec. grid, drop-in biofuels, H2 blend in NG) and/or build dedicated new fuel and carbon management (CCS) infrastructures
- Past energy transitions took many decades, we may face unprecedented rate of change (climate change, tech&market changes).
- Factors affecting energy transition rates: 1) scale/market size; 2) infrastructure complexity; 3) uncertainty about policy, technology
- Need system level learning w/ vehicle and infrastructure.
- Cost for Launching ZEVs
  R&D <<$ invested to “breakeven costs” << $ flows in energy system
- GUIDELINES FOR INFRASTRUCTURE TRANSITION: Portfolio approach; Consistent policy; System level learning; keep transition costs in perspective - potential long term net benefits large, transition costs small; urgent timeline may mean exploring multiple options.

Transport is Key Application for Power to Gas

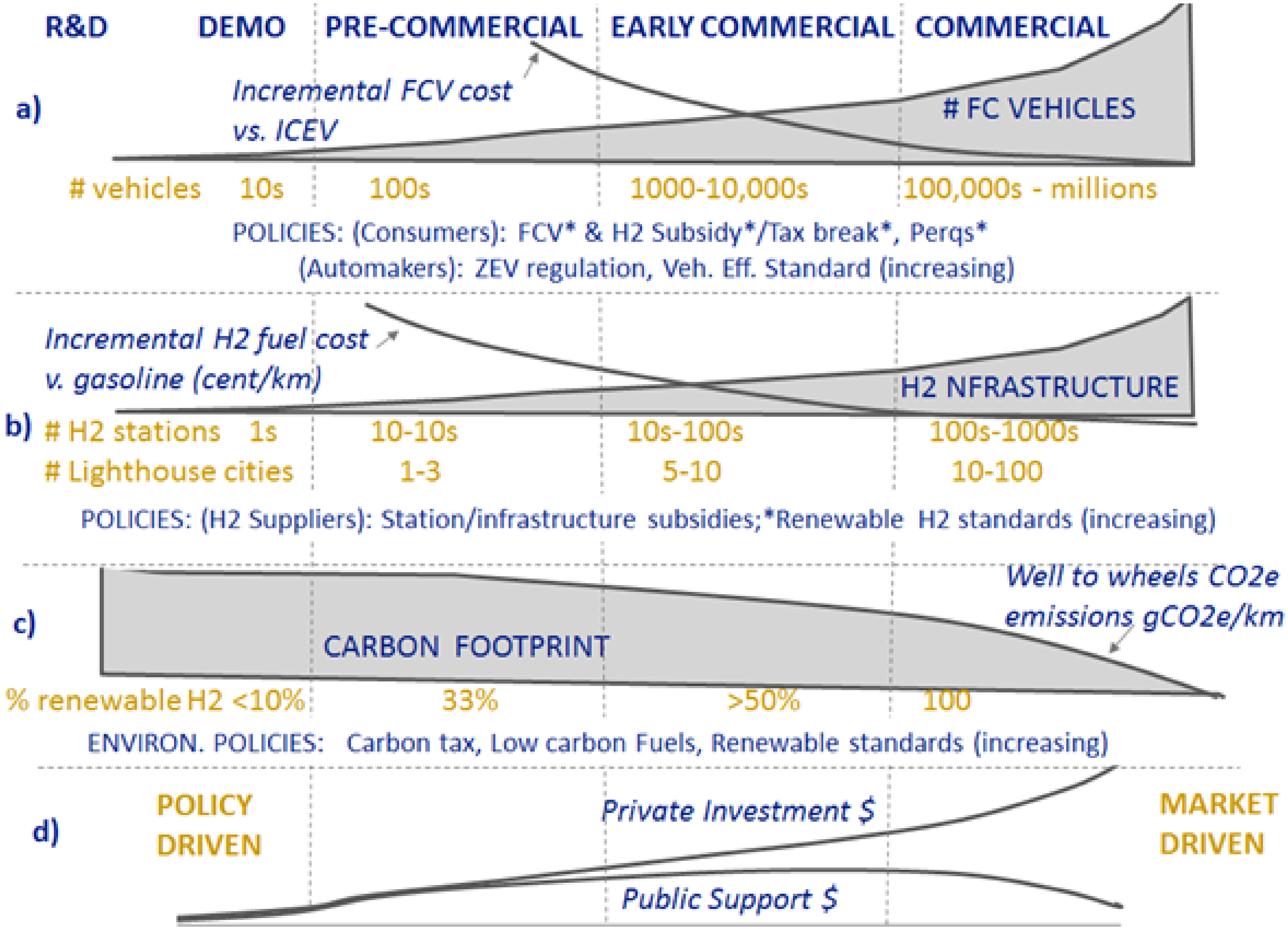


Source: P. E. Franc, "Financing Hydrogen Projects " Nov. 16, 2013, IPHE Conference, Sevilla, SPAIN

PtG offers medium-term business case for H2 transport fuel. In all other sectors (electric, gas, industry, CH4 fuel) PtG unlikely to be economic, even long-term.

Bünger, U., Landinger, H., Pschorr-Schoberer, E., Schmidt, P., Weindorf, W., Jöhrens, J., Lambrecht, U. Naumann, K. Lischke, A. 2014. Power-to-Gas (PtG) in transport: Status quo and perspectives for development, Report to the Federal Ministry of Transport and Digital Infrastructure (BMVI), Germany, AZ Z14/SeV/288.3/1179/UI40. http://www.lbst.de/ressources/docs2014/mks-studie-ptg-transport-status-quo-and-perspectives-for-development.pdf

Infrastructure Buildout Coupled to Other Transitions



* phase out policy once commercialization well established

Unprecedented Rate of Change Ahead?

Meeting 2050 goals to reduce GHG emissions requires rapid transformation of energy system beginning now.

Rapid changes in technology (e.g. very low cost battery or electrolyzer), new consumer patterns (e.g. automated vehicles or ride sharing) may alter future transportation landscape.

Some analysts suggest a “Manhattan Project” to switch to a particular near-zero net carbon energy system ASAP. Others counsel resisting pressure to go big too early.

WHAT DOES THIS MEAN FOR INFRASTRUCTURE?

Guidelines for Infrastructure Transition

Portfolio of future transportation fuels is likely in a low carbon world. Keep range of options open, rather than selecting a single "winning" vehicle technology or fuel too soon.

Persistence, alignment and continuity of policies needed over many decades. Signal that there will be consistent policy over the long term that will adapt to reflect experience. Incorporate externalities into economics.

System level learning needed. It is important to experiment at the network scale and to focus efforts geographically. (e.g. City/regional scale demos of infrastructure & vehicle technologies in networked system.)

Keep costs in perspective:
R&D << System level demo << $ flow in energy system

Expect period of experimentation at system level. Potential net benefits are large. Given the urgency of climate change, may need to explore several options in parallel.

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