

DOCKETED

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California's Dilemma -- Electricity Grid vis-a-vis CO2-emission-free H2 and geothermal systems at total human enterprise scale

California and USA need to avoid over-dependence upon and over-investment in the electricity Grid vis-a-vis complete, optimized, CO2-emission-free energy systems based on (a) gaseous hydrogen (GH₂) and / or liquid ammonia pipelines and / or benign, ubiquitous, baseload, Deep Hot Dry Rock Geothermal (DHDRG) energy.

Please see attachments:

- > Response to DOE RFI FOA # 2529 "H₂ Demonstration Projects ..."
- > Advisory memo to two concurrent H₂ systems studies: (a) Pacific Northwest Renewable H₂ Action plan, (b) A Systems Analysis of the Future Role of Hydrogen in a Carbon-neutral California, before 2050
- > Poster for North America Smart Energy Week, 23-27 Sept 21, New Orleans

Additional submitted attachment is included below.

California's 2050 Energy Dilemma: Hardened Smart Grid, or Hydrogen Pipelines, or Distributed Deep Hot Dry Rock Geothermal (DHDRG)? Think Beyond Electricity

Should CA invest \$ billions in a bigger, smarter, harder Grid? Have we better ways for humanity's total de-GHG-emissions?

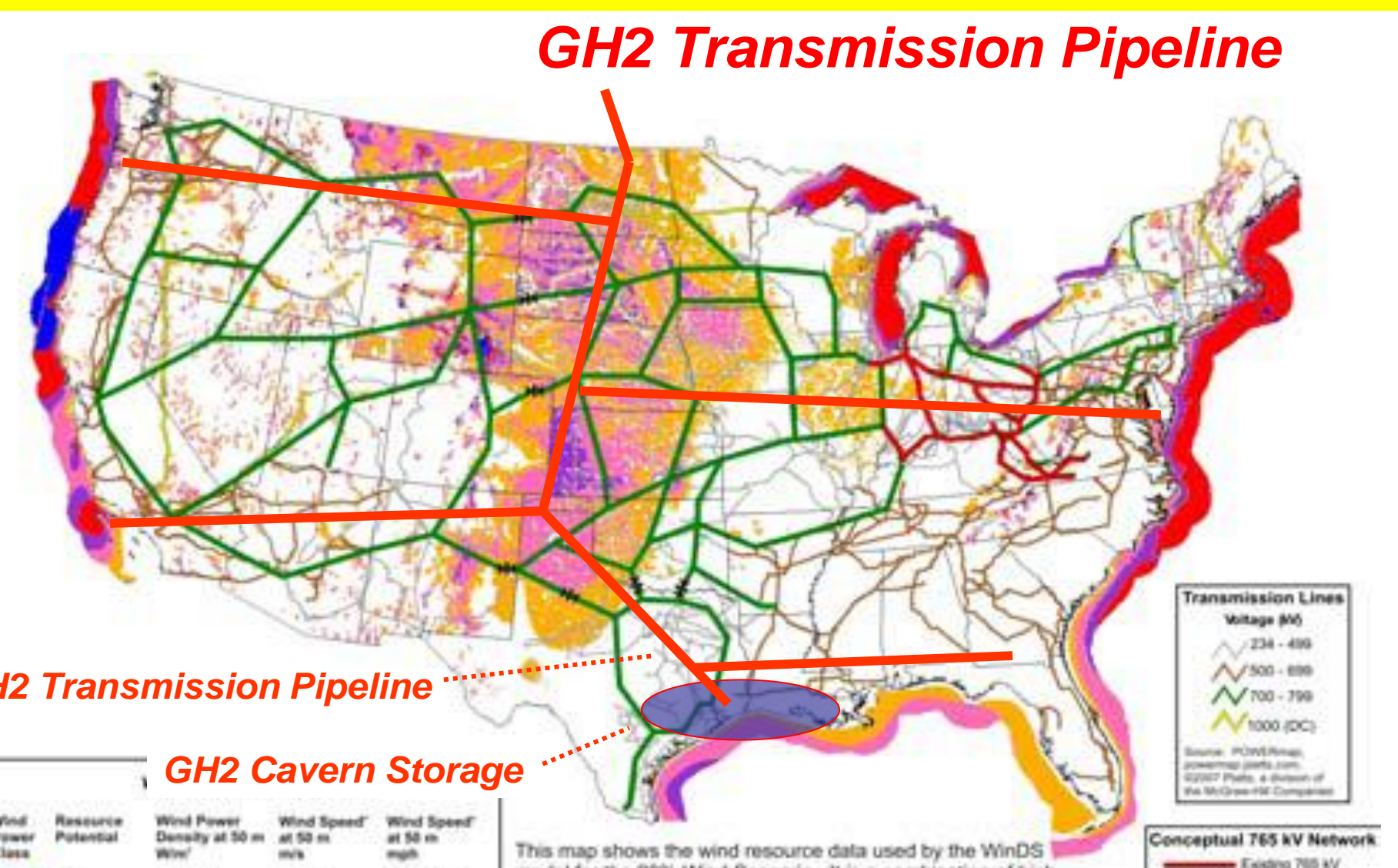
The Leighty Foundation, Juneau, AK www.leightyfoundation.org/earth.php Bill Leighty, Director wleighty@earthlink.net 206-719-5554



Carbon-neutral economy by 2050: All energy plus industrial feedstocks, from CO2-emission-free sources, firm and dispatchable

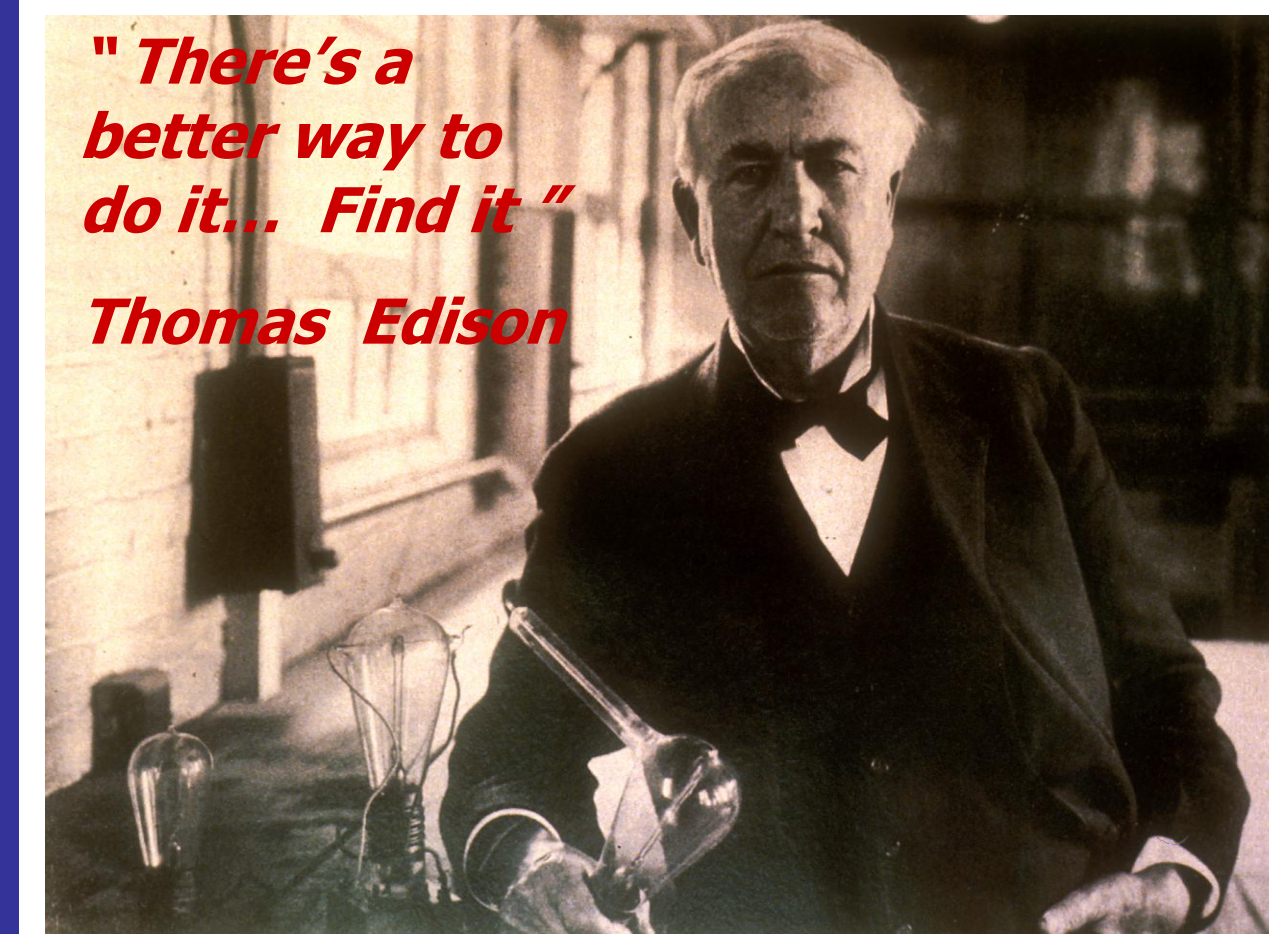
- > Electricity Grid: Large CAPEX required to harden against fires and storms, expand to "electrify everything". NIMBY opposition. Undergrounding very expensive.
 - Avoid over-dependence upon, and over-investment in, the Grid. Technically and economically suboptimal in 2030? 2050?
- > Hydrogen Pipelines: Underground infrastructure, Renewables-source, gathering + transmission + distribution + "free" storage by "packing". Repurpose extant pipelines? New-builds?
- > DHDRG: Deep (6 – 10 km) Hot Dry Rock Geothermal systems: Benign, inexhaustible, indigenous, baseload, firm and dispatchable, nearly ubiquitous on Earth, equitable
 - The ultimate in Distributed Energy Resources (DER): All electric and thermal energy via loosely-connected micro- and mini-grids PLUS industrial feedstocks. Local and autonomous.
 - No transmission nor storage needed: Nearly ubiquitous on Earth. Leave the heat in the ground until needed. Needs gathering and distribution, not transmission.
 - Obsoletes wind, solar, other Variable Energy Resources (VER's)? No large, distant plants requiring transmission? Lower delivered long-term COE, almost anywhere in California, on Earth?
 - Should California invest now in nascent boring technologies to accelerate installation of profitable DHDRG access, harvest, and delivery systems? Build a novel industry?

Gaseous Hydrogen (GH2) pipelines vis-à-vis Grid: Underground, lower cost, gathering + transmission + distribution
"Free storage" by "packing" pipelines to Maximum Allowed Operating Pressure (MAOP); unpack to ~ 1/3 MAOP, for VER's



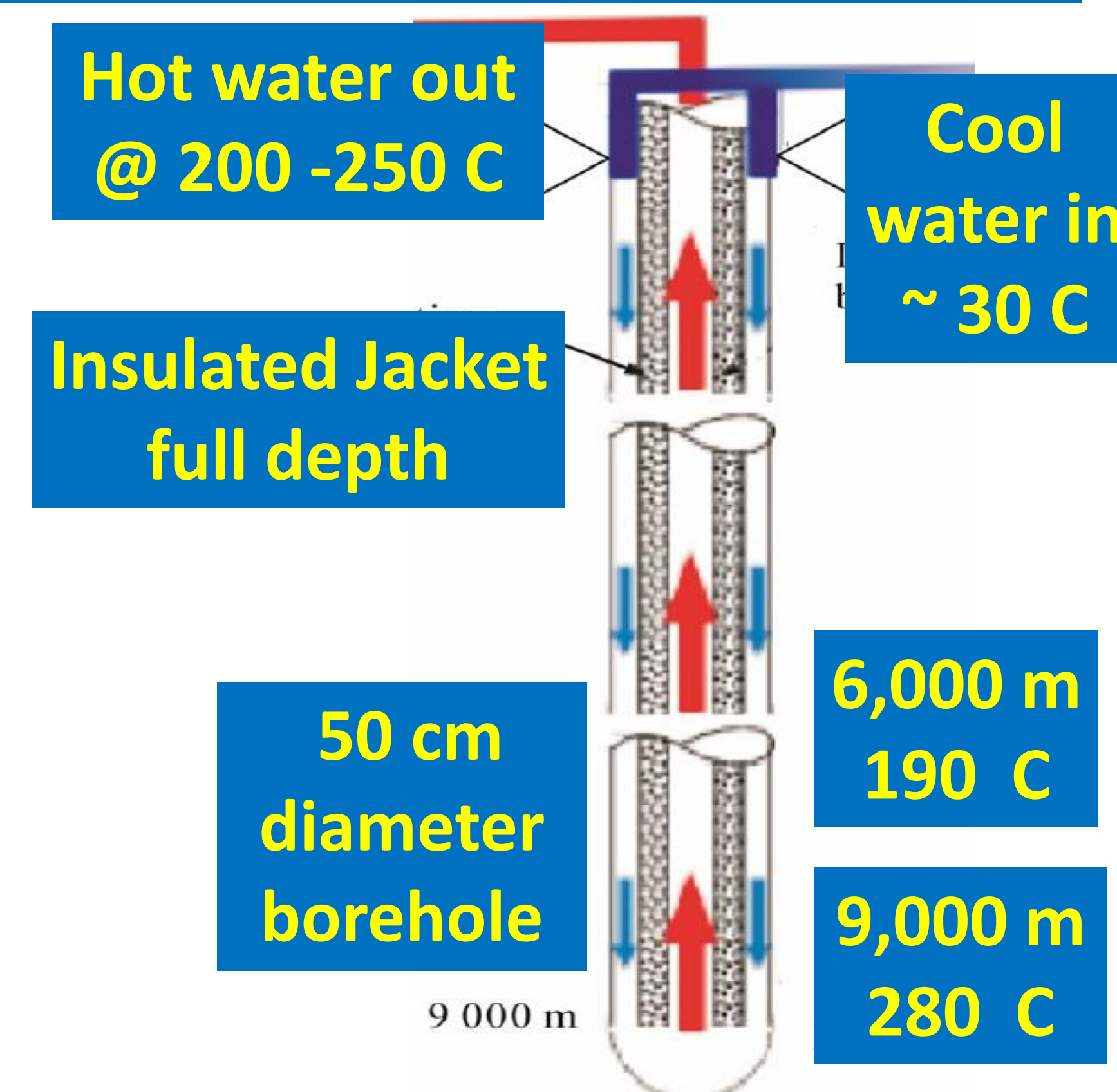
36" = 8 GW gaseous Hydrogen @ 100 bar
Convert Palm Springs to Long Beach Natural Gas Pipeline?

Smart Pipe Technologies, Houston
Polymer-metal linepipe avoids hydrogen embrittlement.



- DHDRG potential: Can we bore "Deep enough, Cheap enough"?**
- » Low-cost, non-abrasive, rock breaking technology: no "fracking" at depth
 - » No rotary drill rig needed: compact, transportable equipment
 - » Cuttings (chips) removed by conventional mud hose return
 - » Proof-of-concept by European collaborative to 200 m in 2000's: NO, RU, CH
 - » Critical component needed: Down Hole Pulse Generator (DHPG)
 - » Worldwide IP not advanced; DHPG plus boring R&D are key → TRL 8

Closed loop system: minimum leak risk

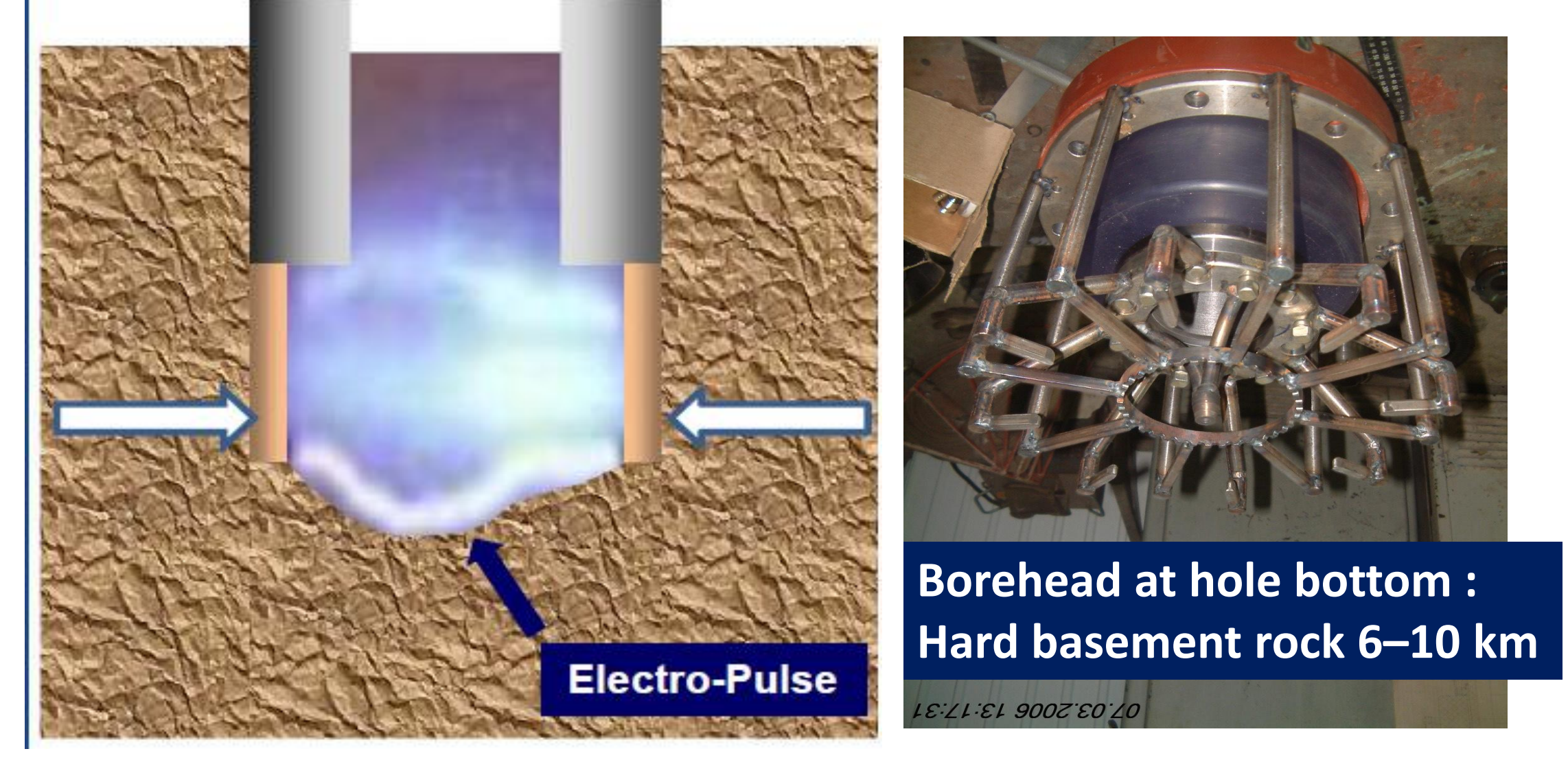
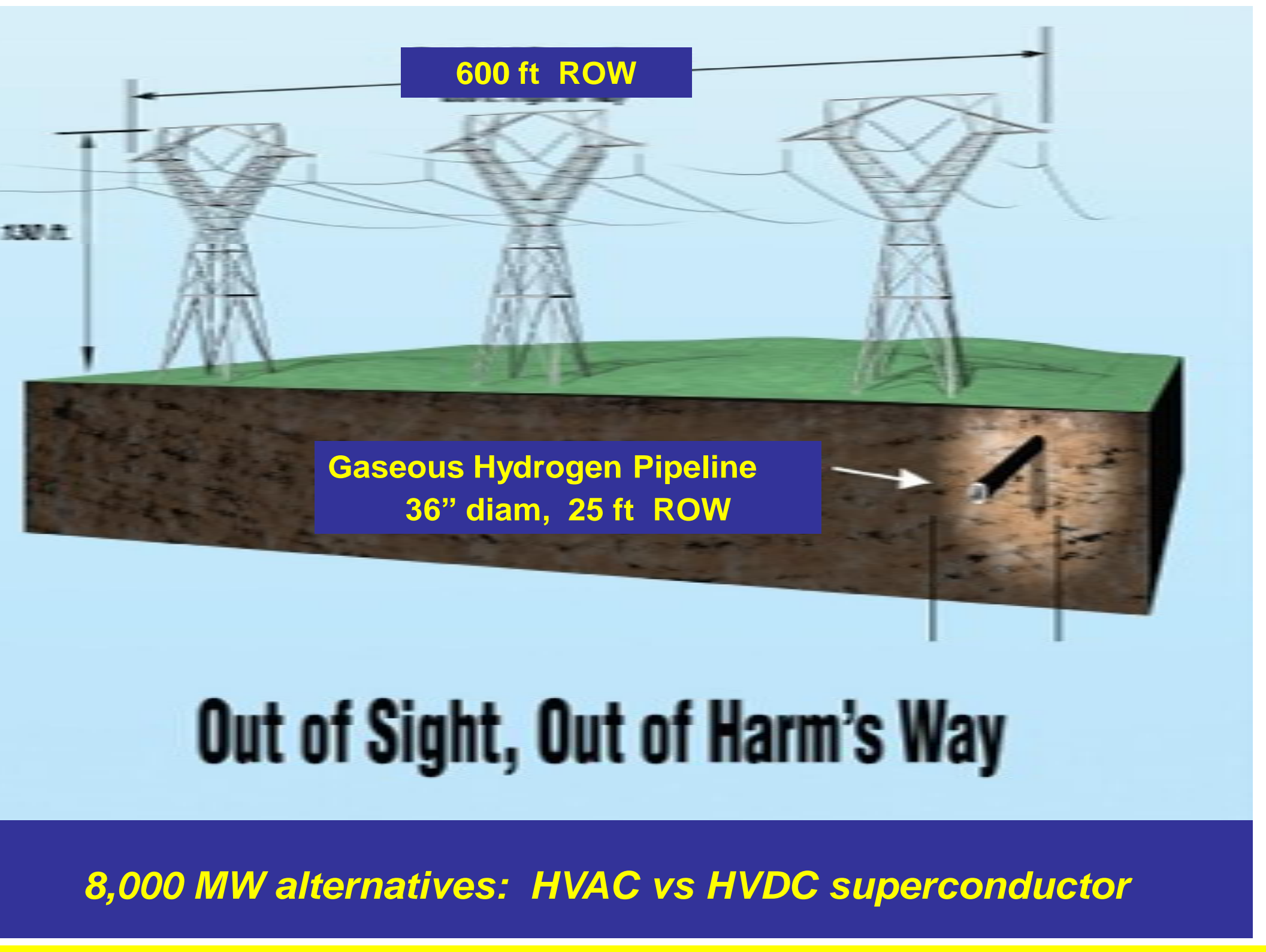


Wind Potential ~ 10,000 GW
"H2@Scale" Hydrogen needs regional-to-continental optimized transmission-plus-cavern-storage systems

- 860,000 m3 physical
- 150 bar = 2,250 psi
- 2,500 Mt net = 92,500 MWh
- \$15M avg cap cost / cavern
- \$160 / MWh = \$0.16 / kWh
- Cavern top ~ 700m below ground

Domal Salt Storage Caverns
Texas
"Clemens Terminal" Conoco Phillips 20 years
Praxair '07
PB ESS

Gaseous Hydrogen pipeline transmission CAPEX, OPEX lower than wind & PV via Grid



- Electro Pulse Boring: EPB for DHDRG**
- Deep geothermal heat: 240 C @ 8 km
 - Electricity + DHS heat, anywhere
 - Low-cost rock breaking, remote area
 - No rotary abrasive drilling; no drill rig
 - Goal: \$ 150 / m, 50 cm diam, 5-10 km
 - Hose return cuttings to surface
 - Casing needed only through topsoil, aquifers

36" Gaseous Hydrogen (GH2) pipeline capacity = 8 GW @ 100 bar;
One 36" pipeline 1,600 km long stores ~ 120 GWh by "packing": no cost

- DHDRG critical path to commercialization from ~ TRL 3 today: Should California risk investment, to invent and deploy?**
- » Design, build, test Down Hole Pulse Generator (DHPG) to operate at full depth T and P, at 6 – 10 km
 - » ~ \$ 30 million: proof-of-concept test borings to 3 km
 - » ~ \$ 150 million: test borings to 5 – 10 km; design revisions for commercialization; pre-production EPB components: achieve TRL 8
- Goals: EPB technology, to enable California's 2050 goals, without new Grid or pipeline transmission, storage, or fracking
- » \$ 150 per meter depth, constant, to 5 – 10 km: ~ \$ 2 million @ 10 km marginal cost
 - » Rate Of Penetration (ROP) = 1 m / minute @ 10 – 20 pulses per second (pps)
 - » \$ 0.02 / kWh (thermal) wellhead @ 200 + C: Organic Rankine Cycle (ORC) electricity + District Heating & Cooling System (DHCS)
 - » \$ 0.04 / kWh (electric) at Organic Rankine Cycle (ORC) generator, baseload, dispatchable; via micro- and mini-grid proliferation
 - » Affordable, inexhaustible, baseload, benign, equitable, energy almost anywhere in California, and on Earth: limited by topsoil, aquifers

