UCI

NATIONAL FUEL CELL RESEARCH CENTER

Role of Hydrogen in Energy Future

for: Sacramento Municipal Utility District

from: San Diego Union Tribune

Prof. Jack Brouwer, Ph.D., Director

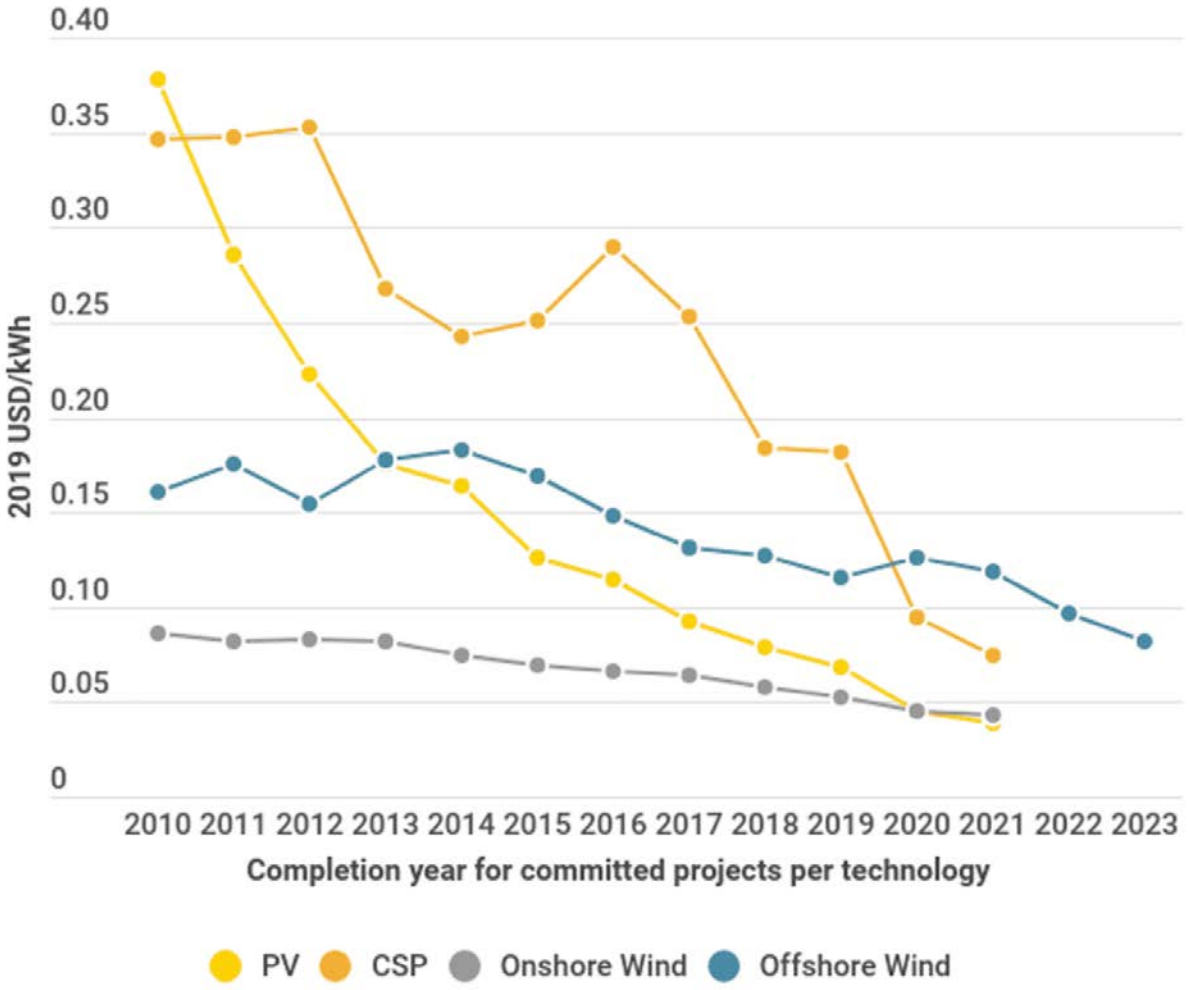
Public comment may be submitted via e-mail to PublicComment@smud.org.

Adopt More Solar & Wind

We must increasingly adopt energy conversion that is sustainable & naturally replenished quickly

Good News!

- Widely available around world
- Now typically cheapest form of primary energy



From: IRENA, www.irena.org/newsroom/pressreleases/2020/Jun , 2020

Directly Use More Renewable Electricity

- Electrify buildings, especially residential new construction – but not all built environment demand is amenable and some infrastructure upgrades are too costly
- Always use renewable electricity directly whenever possible (demand management)
- Store in electrochemical battery energy storage systems first (most efficient storage) – but some uses require rapid fueling, long range, heavy payload (fuel cells)
- Battery electric vehicles (BEV) & fuel cell electric vehicles (FCEV) are important





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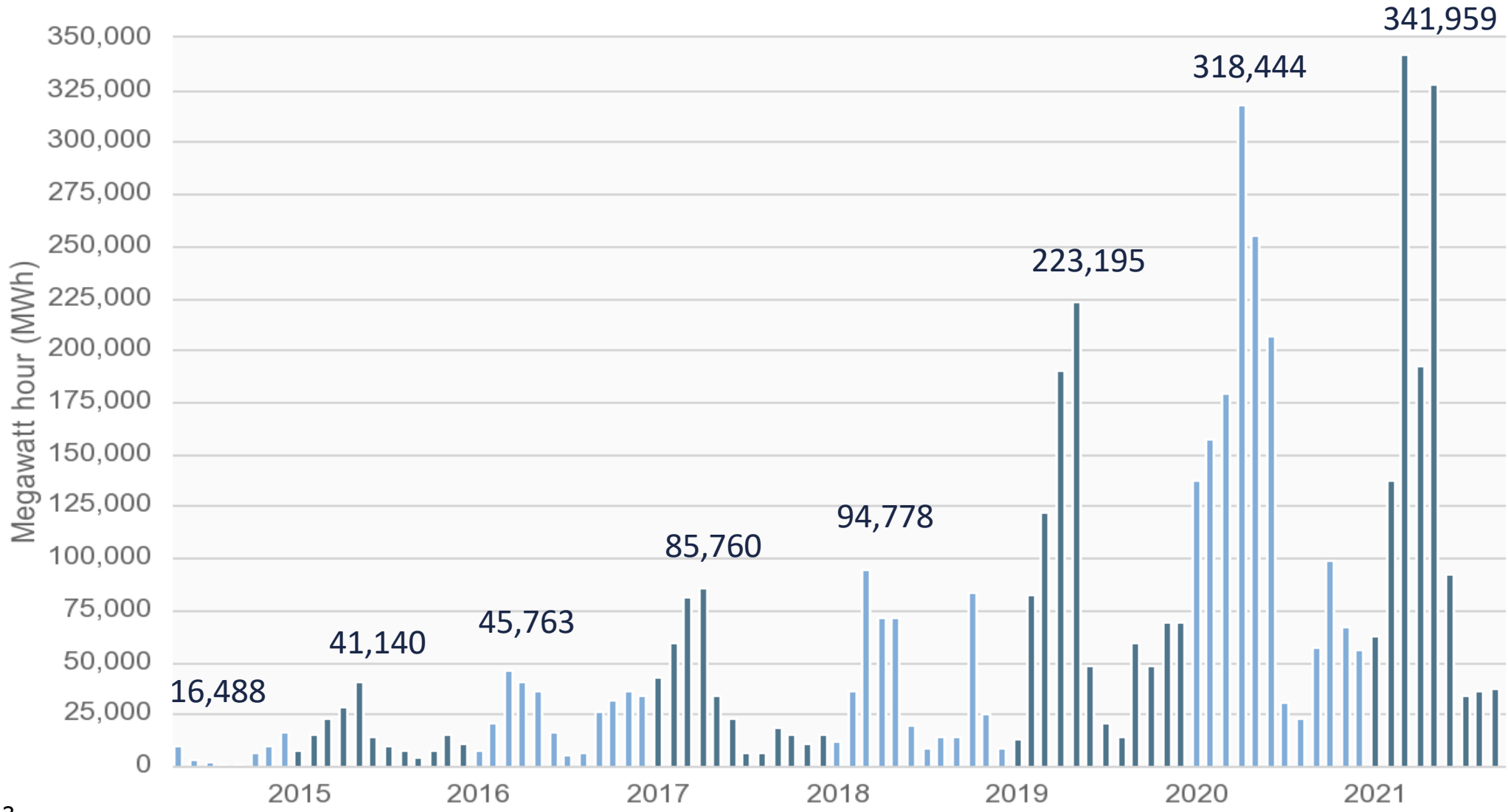
High Renewable Use is Challenging (Curtailment in CA)



UCI

California ISO

CAISO PUBLIC

Board Strategic Development Committee and Special SMUD Board of Directors Meeting

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NFCRC

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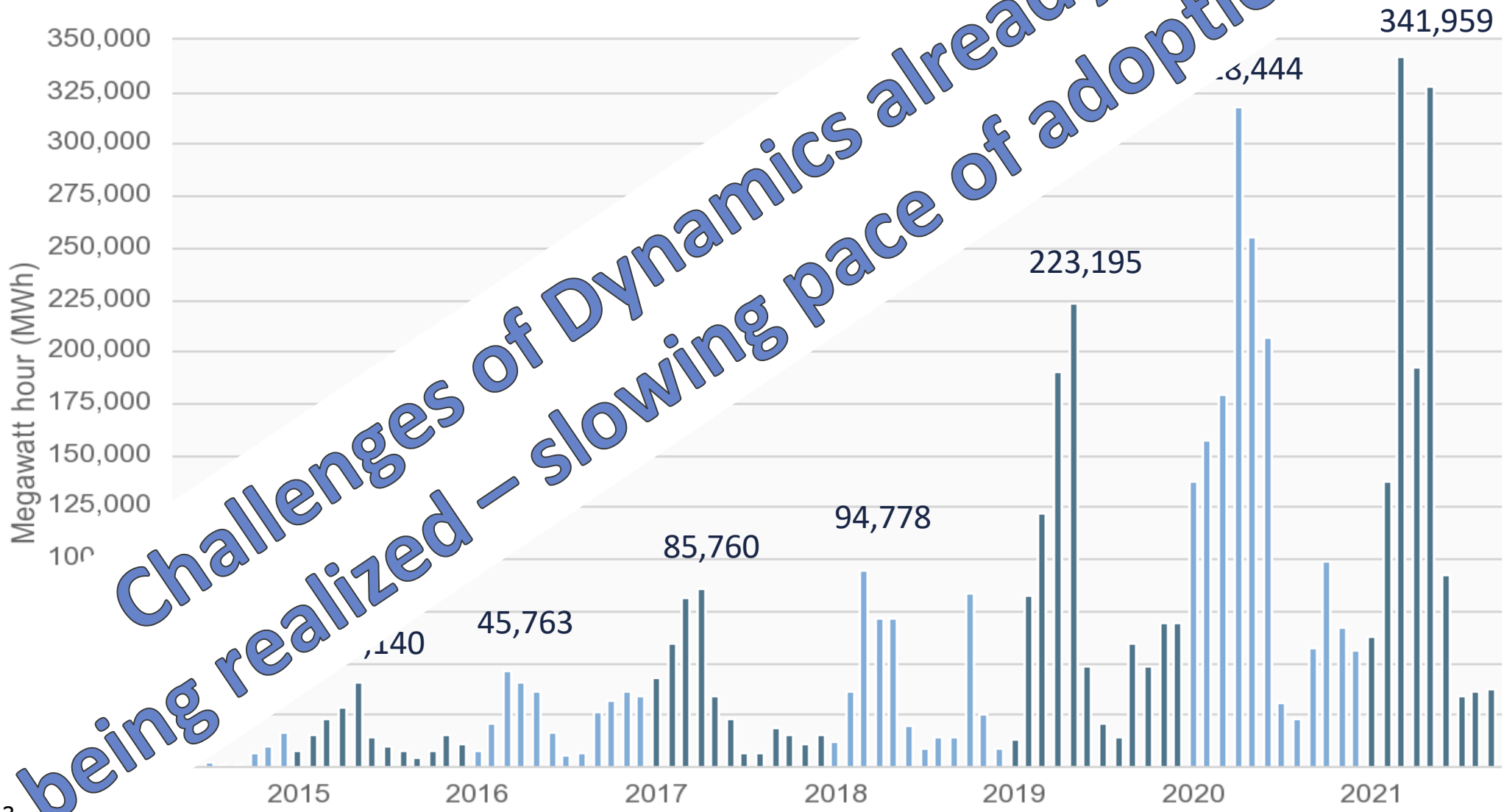
High Renewable Use is Challenging (C… CA)



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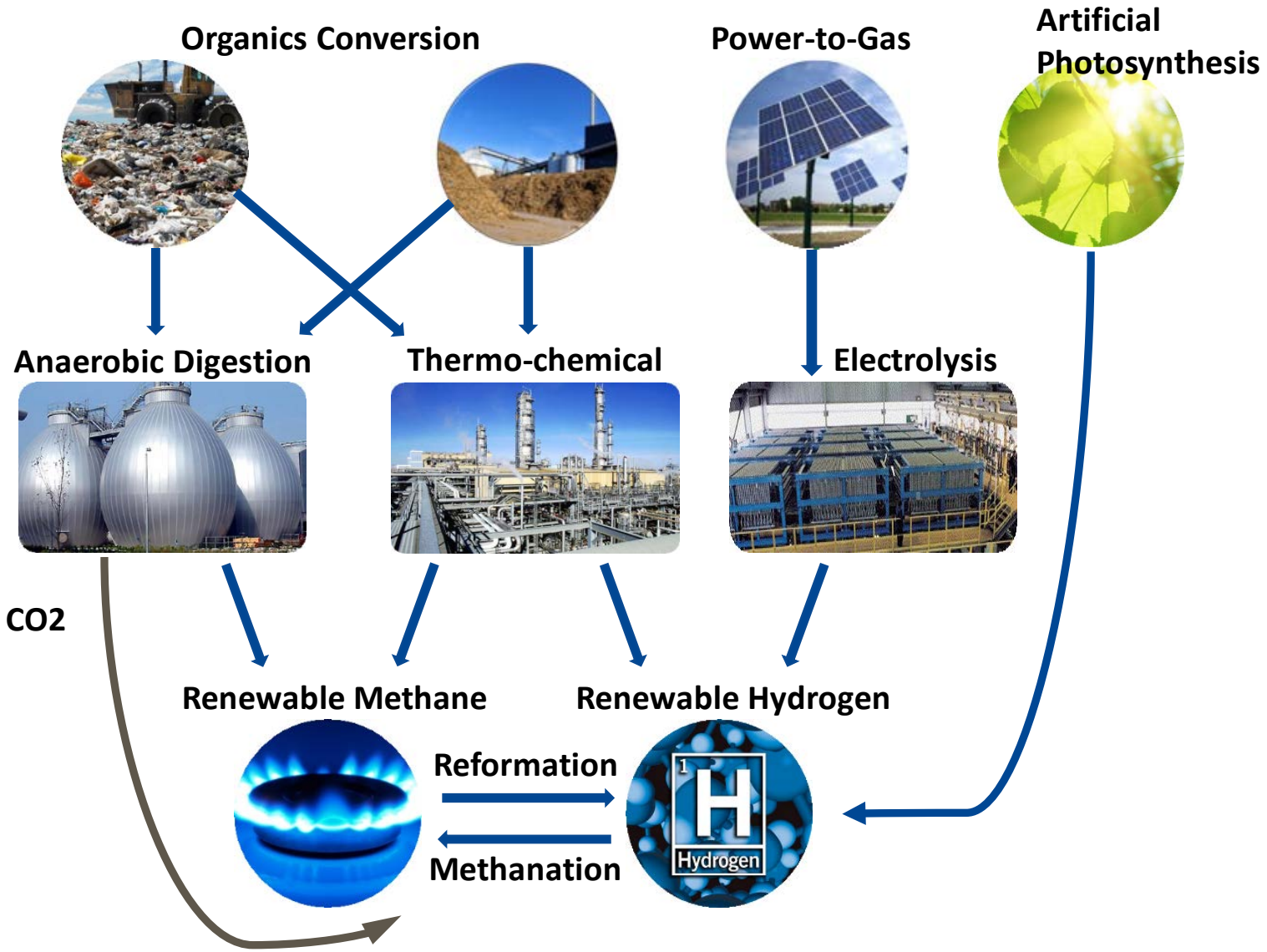
Renewable and Zero-carbon Gaseous Fuel Pathways

- "Green" in the traditional sense of environmentally sensitive and desirable



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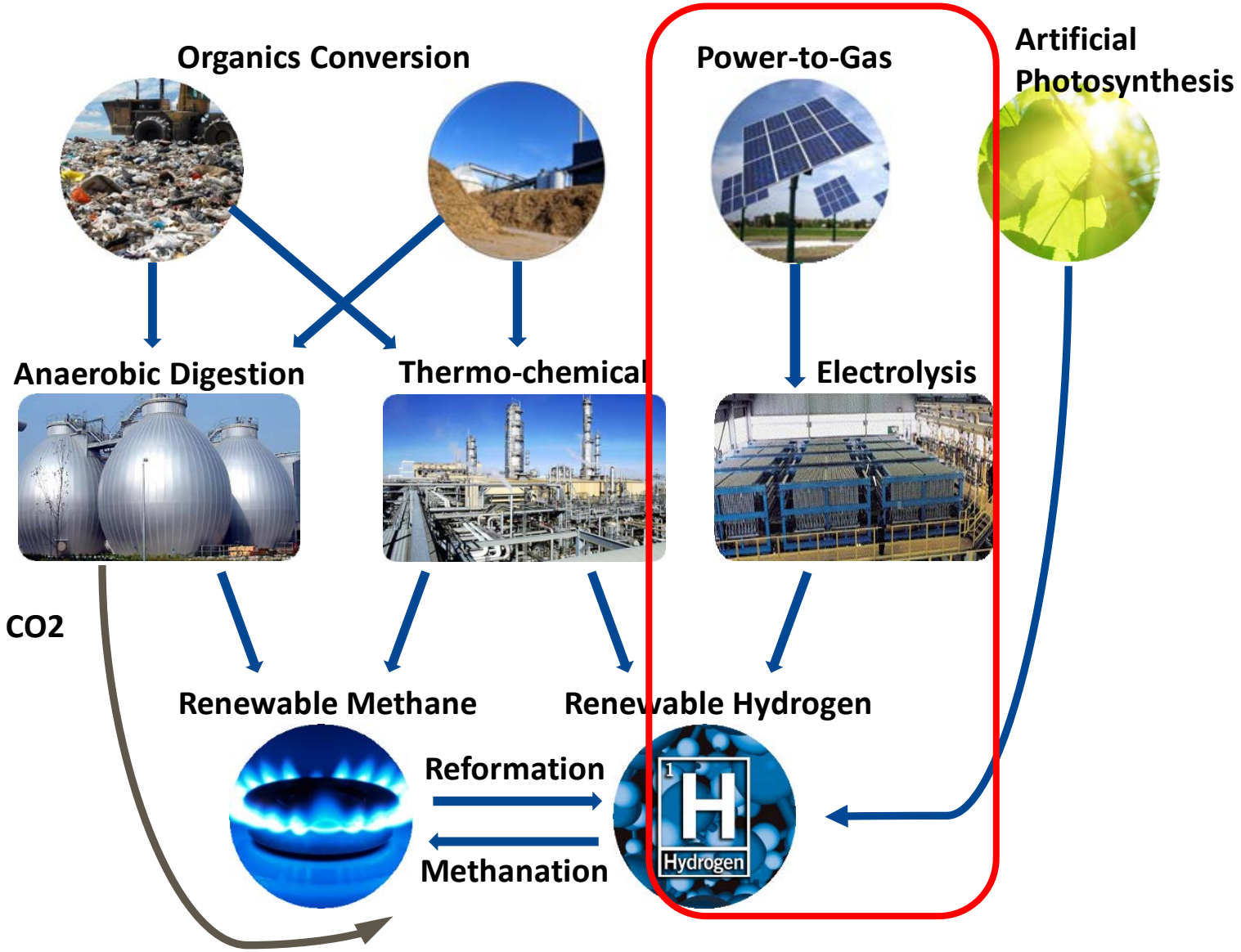

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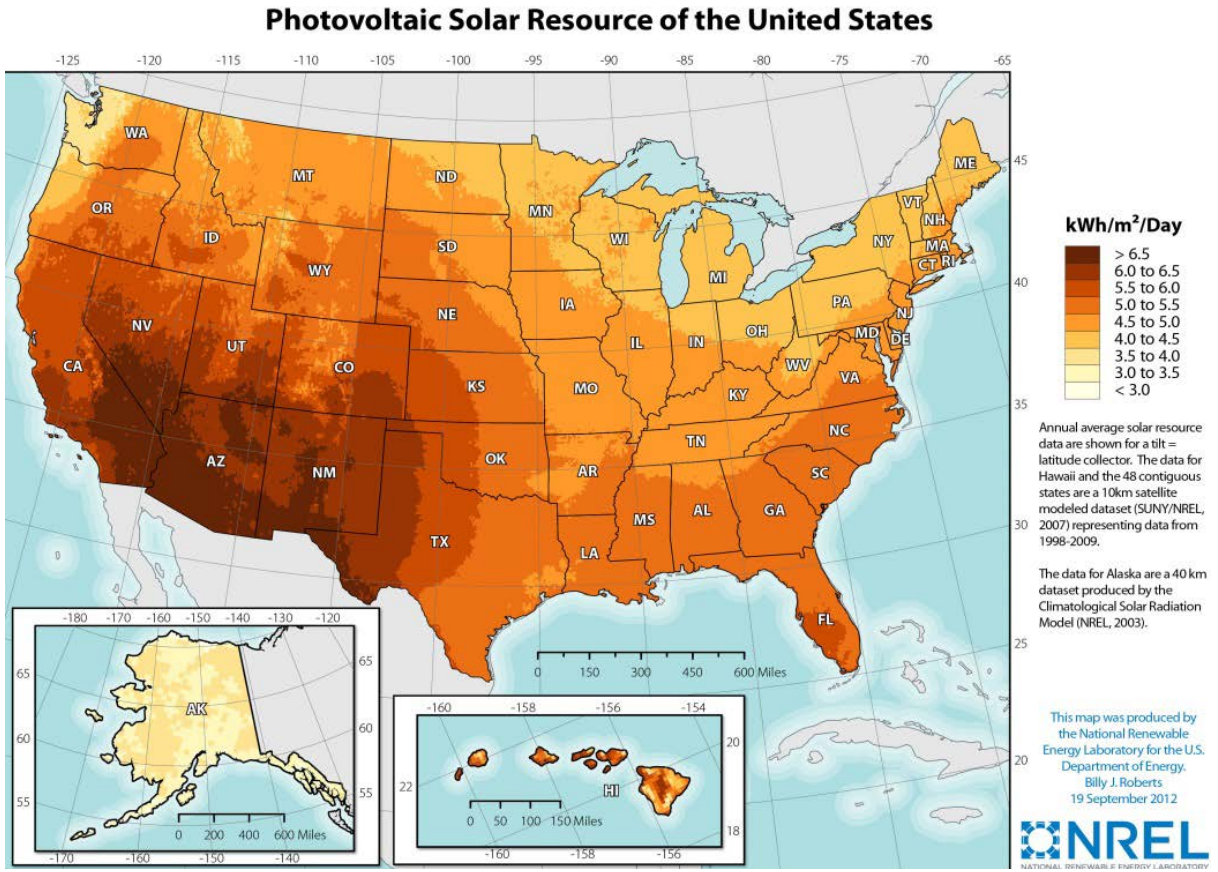
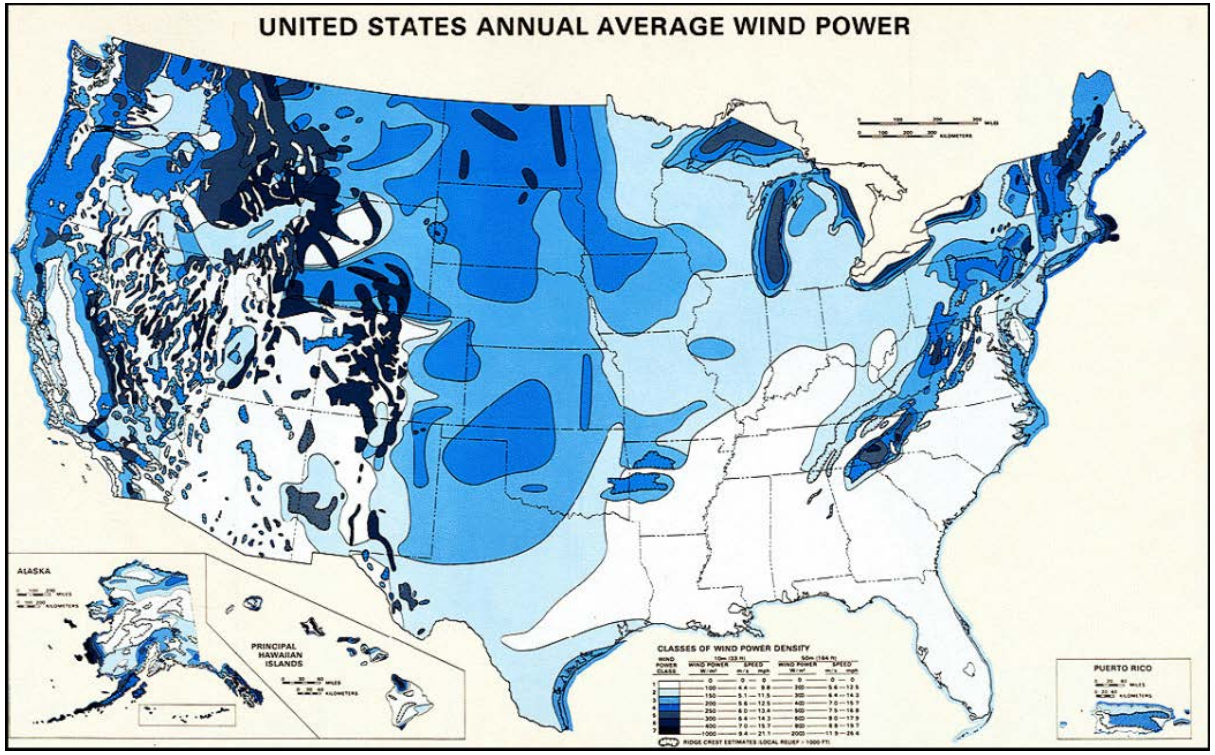
Solar & Wind Power – most widely available resources

- Renewable future will be more equitable all around the world





NREL, 2018

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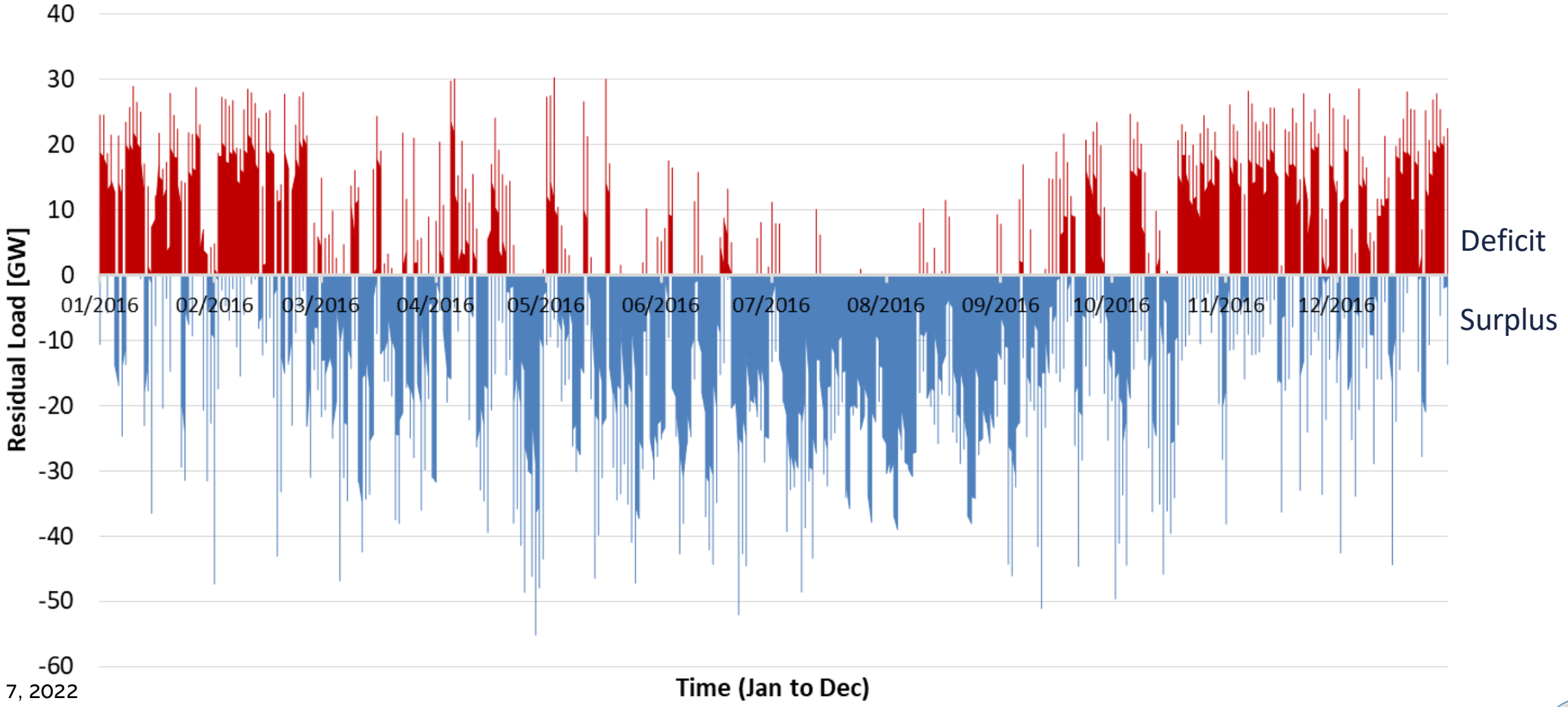
Dynamics of Renewable Future are Challenging

- Wind dominant case (37 GW solar capacity, 80 GW wind capacity)



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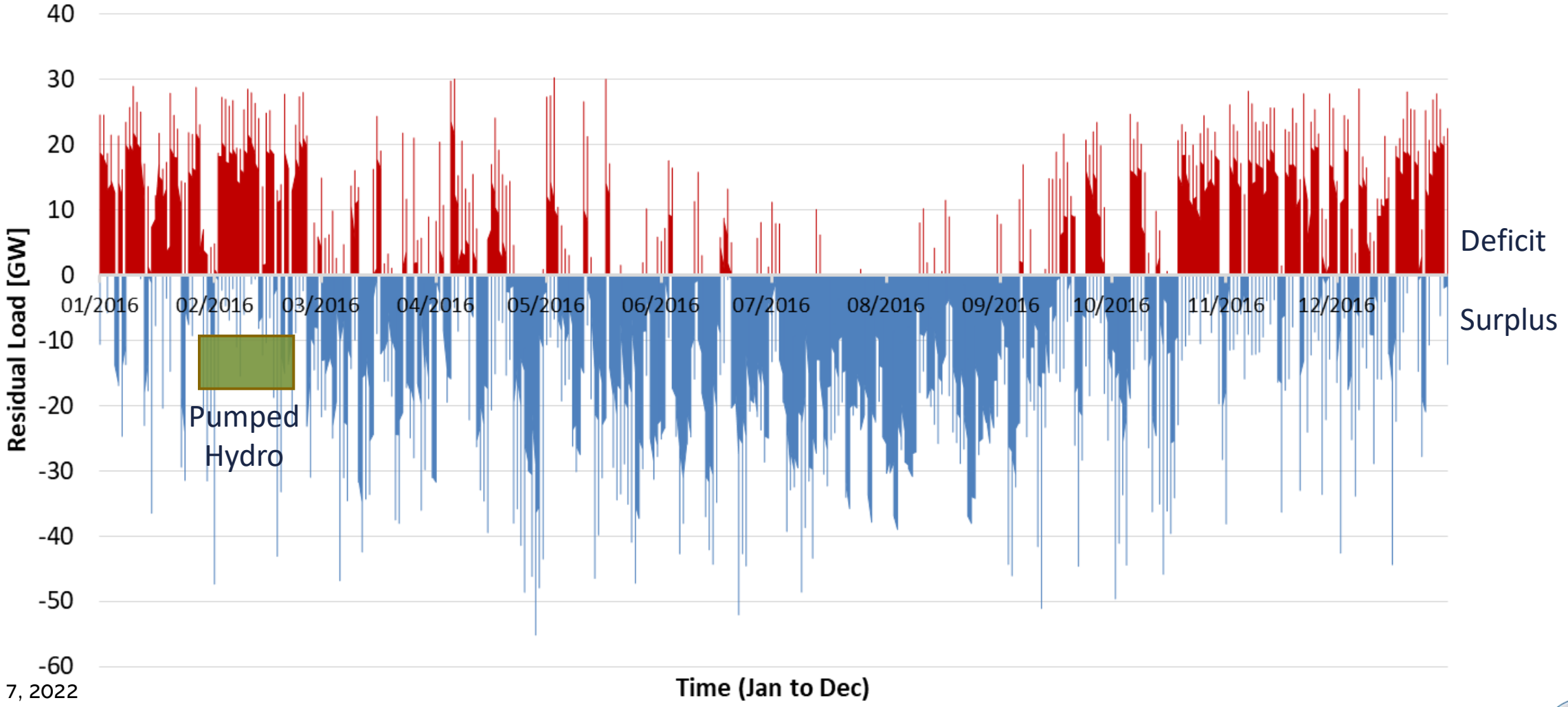

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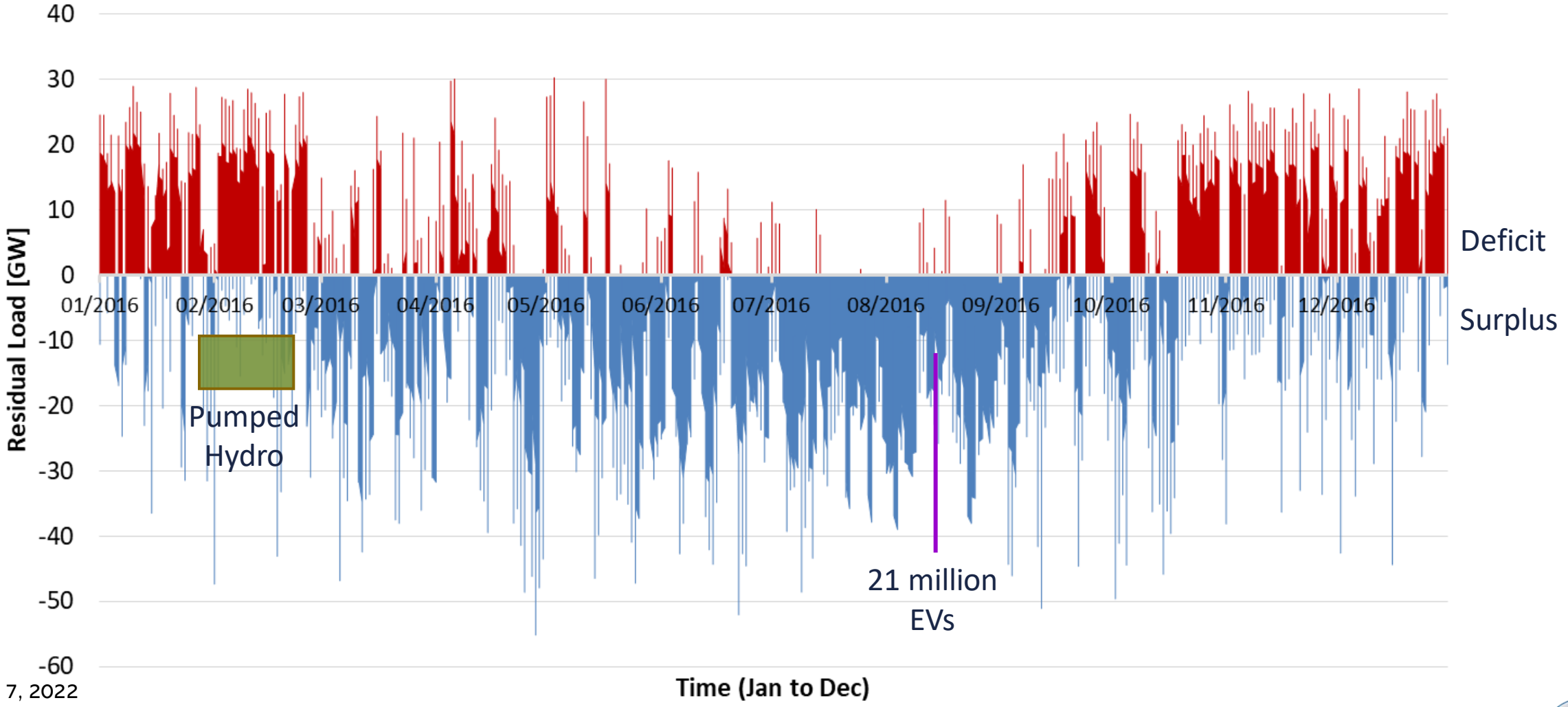

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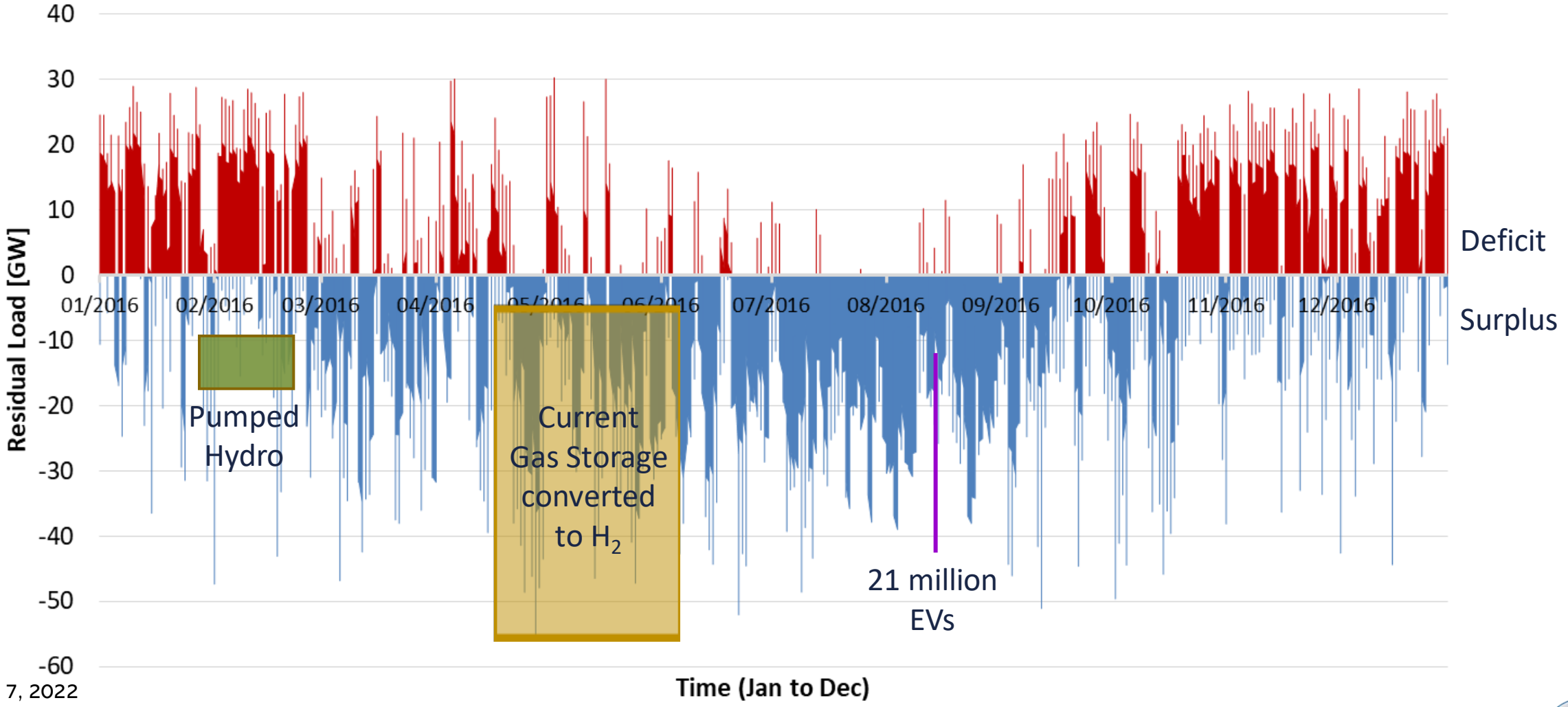

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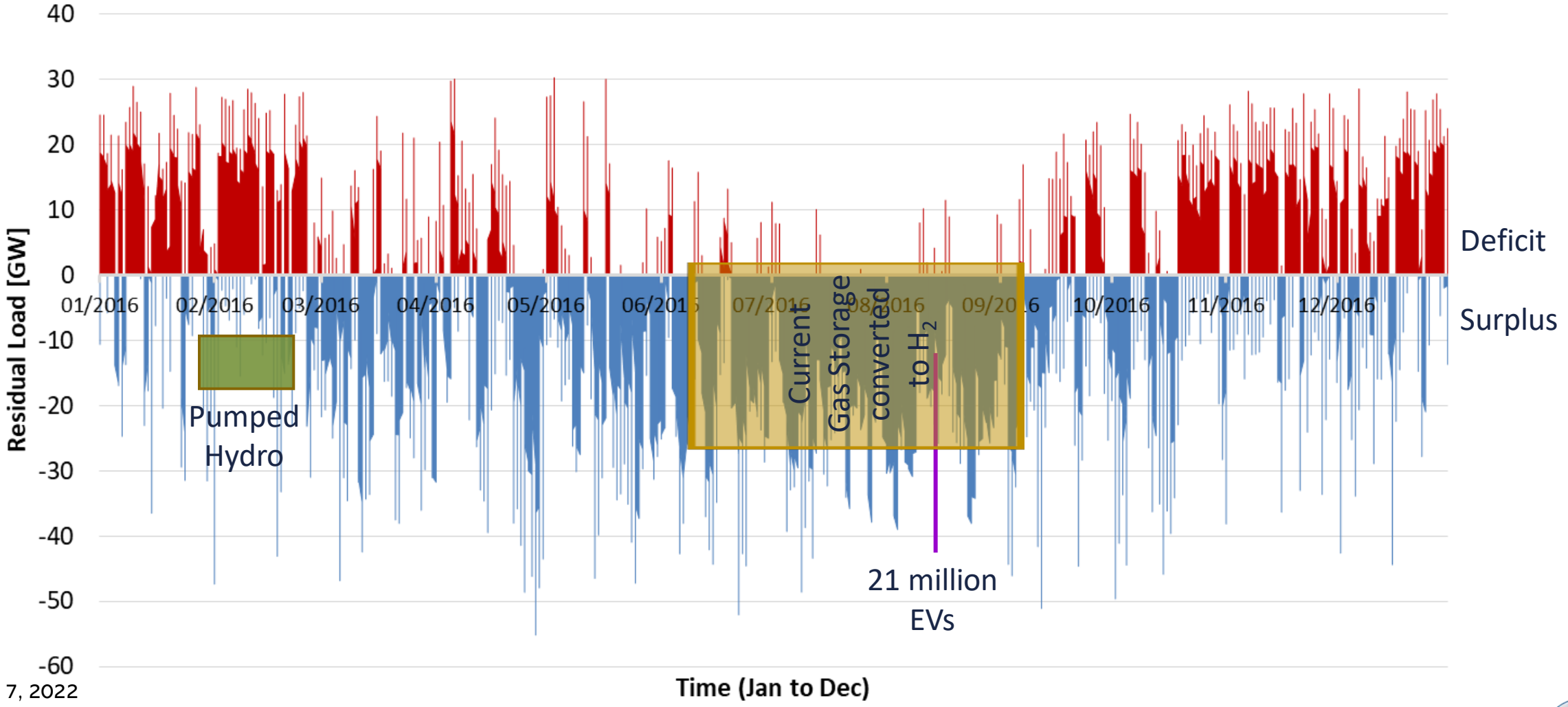

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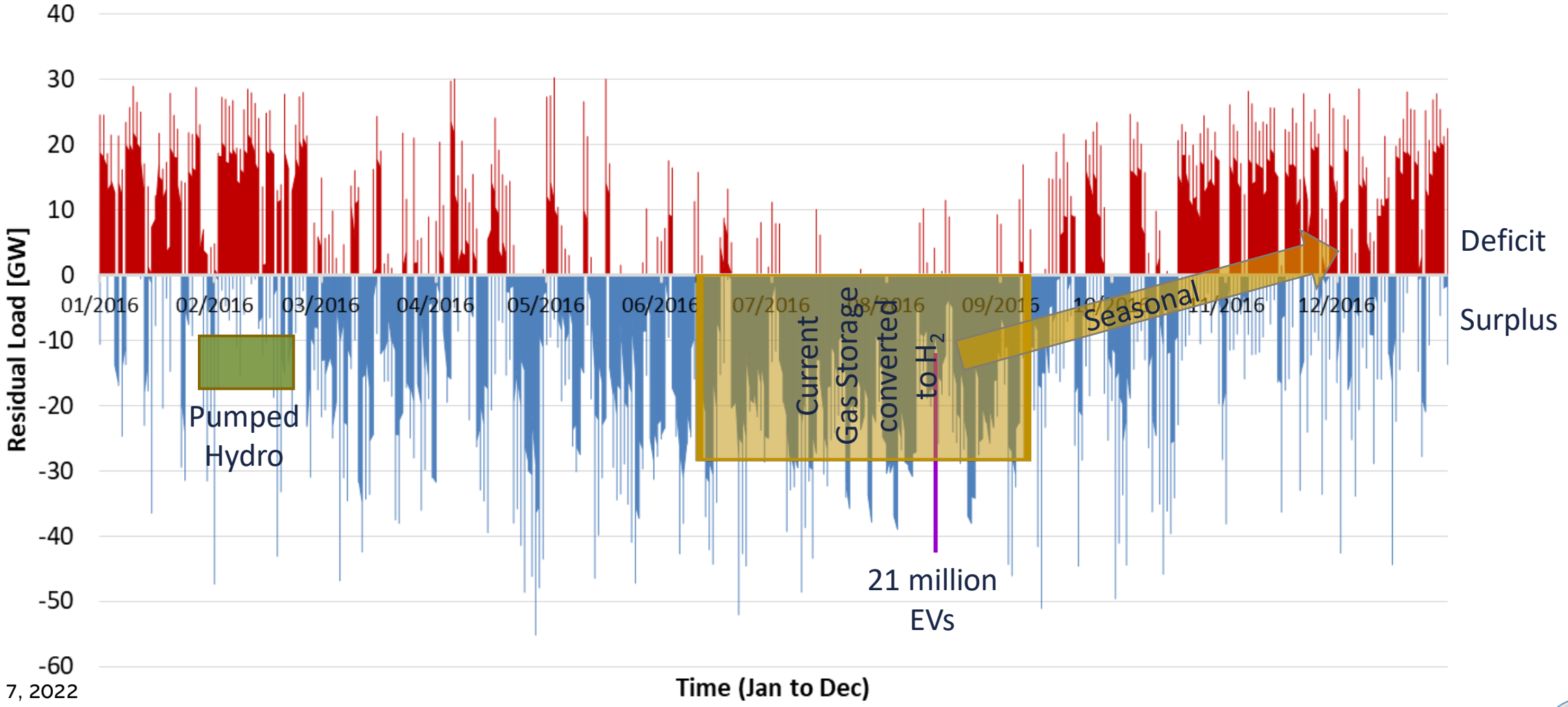

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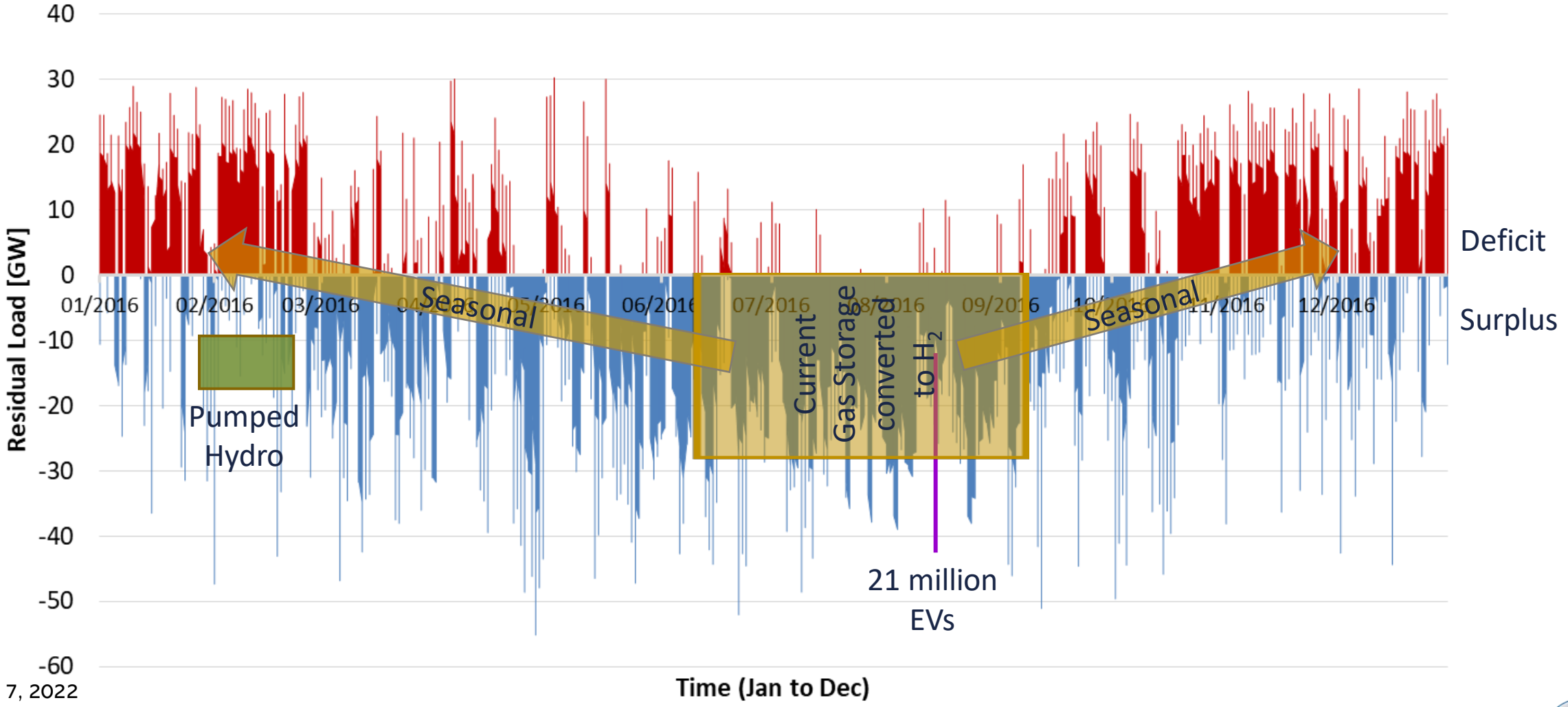

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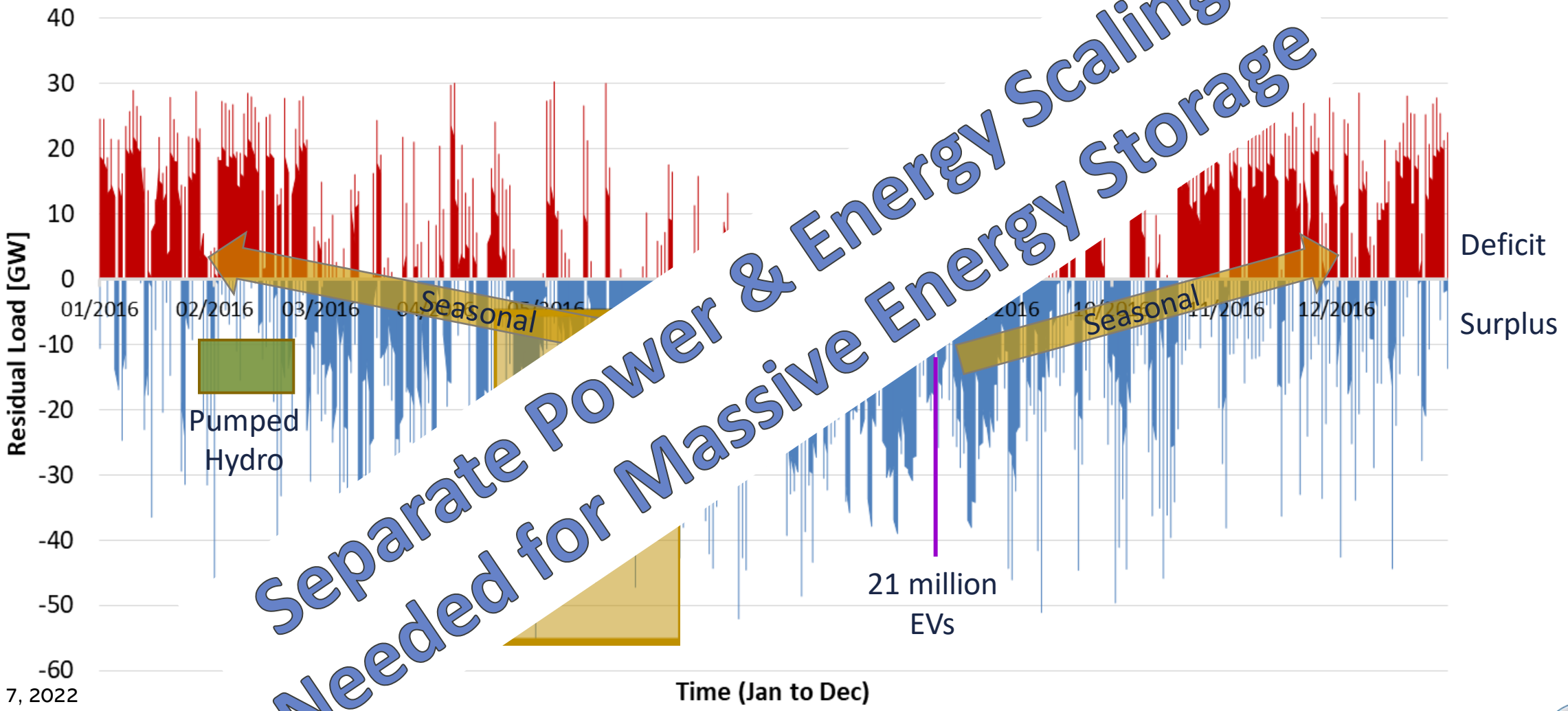

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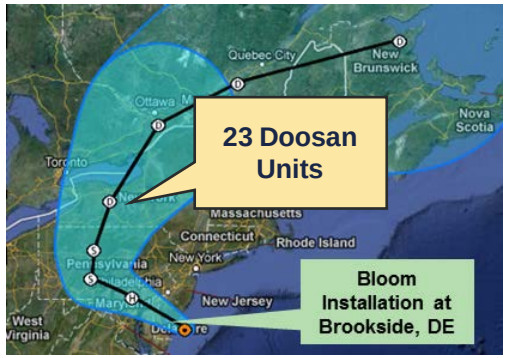
Demonstrated Resilience of Fuel Cells and Gas System

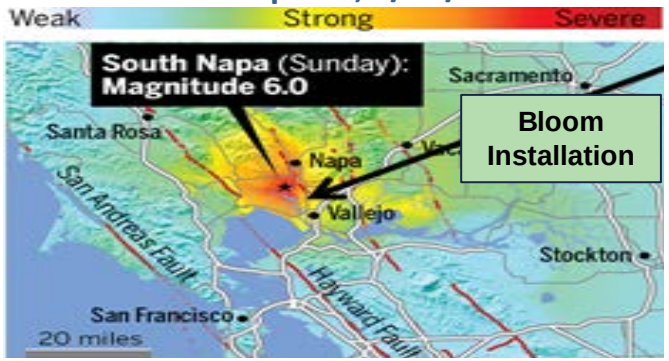
San Diego Blackout, 9/28/11

Winter Storm Alfred, 10/29/11

Hurricane Sandy, 10/29/12



CA Earthquake, 8/24/14

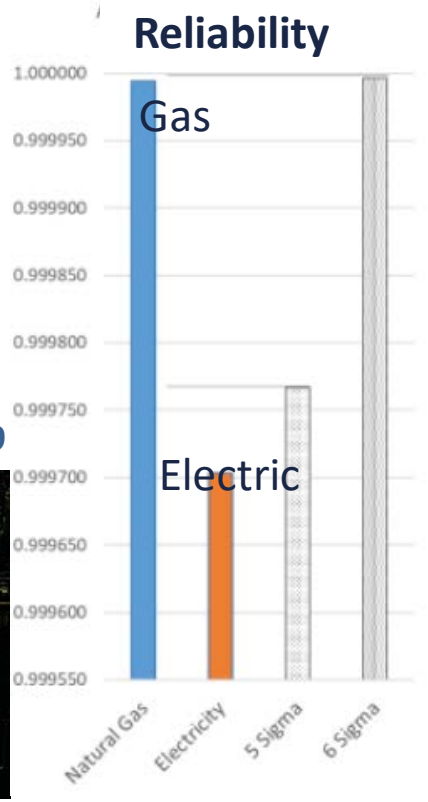


Data Center Utility Outage, 4/16/15

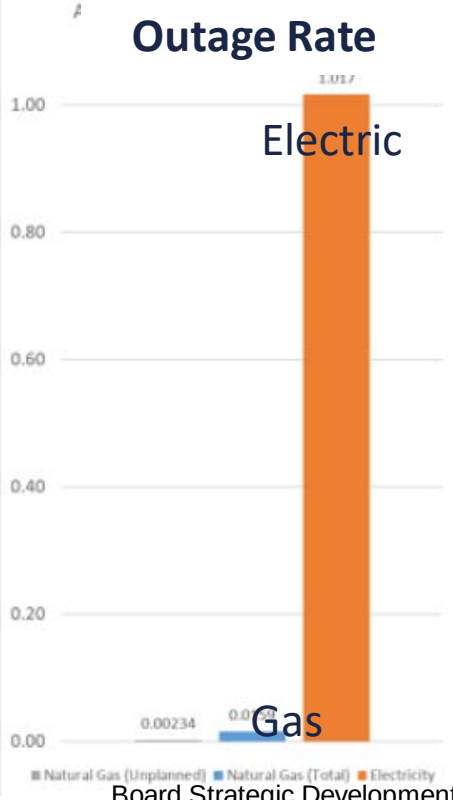
Hurricane Joaquin, 10/15/15

Napa Fire, 10/9/17

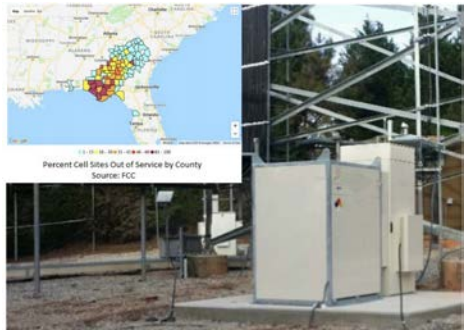
Reliability



Outage Rate



Hurricane Michael, 10/15/18



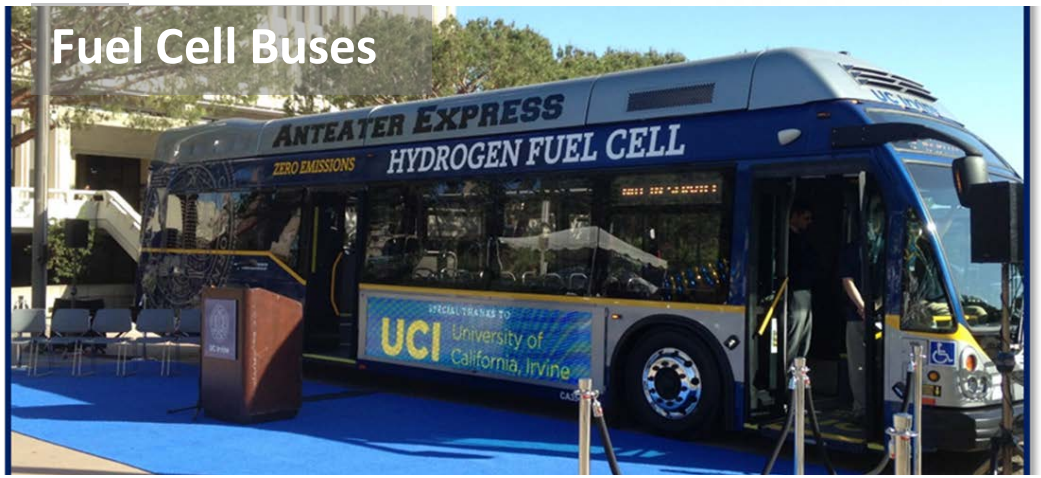
Ridgecrest Earthquakes, 7/4-5/19

Manhattan Blackout, 7/13/19

Liss, W., & Rowley, P. (2018). *Assessment of natural gas and electric distribution service reliability*. Gas Technology Institute.

Why Hydrogen? Zero Emission Fuels Required

- Provide zero emissions fuel to difficult end-uses



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Anything that requires (1) rapid fueling, (2) long range, (3) large payload

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Why Hydrogen? Industry Requirements for Heat, Feedstock,

- Many examples of applications that cannot be electrified

Steel Manufacturing & Processing

Cement Production

(Photo: ABB Cement)

Plastics

(Photo: DowDuPont Inc.*)*

Ammonia & Fertilizer Production

(Photo: Galveston County Economic Development)

Computer Chip Fabrication

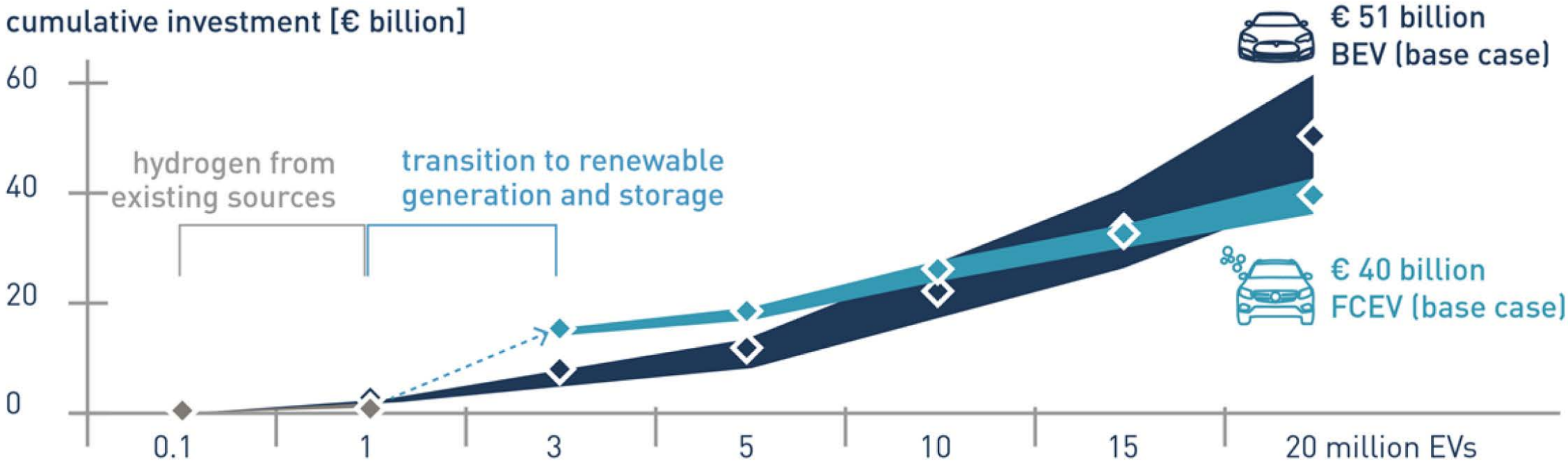
(Photo: American Chemical Society)

Pharmaceuticals

(Photo: Geosyntec Consultants)

Infrastructure Limits Require both FCEV & BEV

Comparative Analysis of Infrastructures: H2 & FCEV vs. Grid & BEV



Robinius, Martin, Jochen Franz Linßen, Thomas Grube, Markus Reuß, Peter Stenzel, Konstantinos Syranidis, Patrick Kuckertz, and Detlef Stolten. *Comparative analysis of infrastructures: hydrogen fueling and electric charging of vehicles*. Forschungszentrum Jülich GmbH, Zentralbibliothek, Verlag, 2018.

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U.S. DOE “Hydrogen Energy Earthshot”

- Accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade - $9.5 billion in federal funding allocated

Office of Energy Efficiency & Renewable Energy » Hydrogen Shot

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

- Reduce RH_2 cost from ~$5/kg to $1/kg to unlock new markets for hydrogen, including steel manufacturing, ammonia, energy storage, and heavy-duty trucks

1 Dollar

1 Kilogram

1 Decade