The future of renewable gas: biomethane and green hydrogen

Sergey Paltsev
Massachusetts Institute of Technology

MIT Center for Energy and Environmental Policy Research

MIT Joint Program Science Policy Global Change

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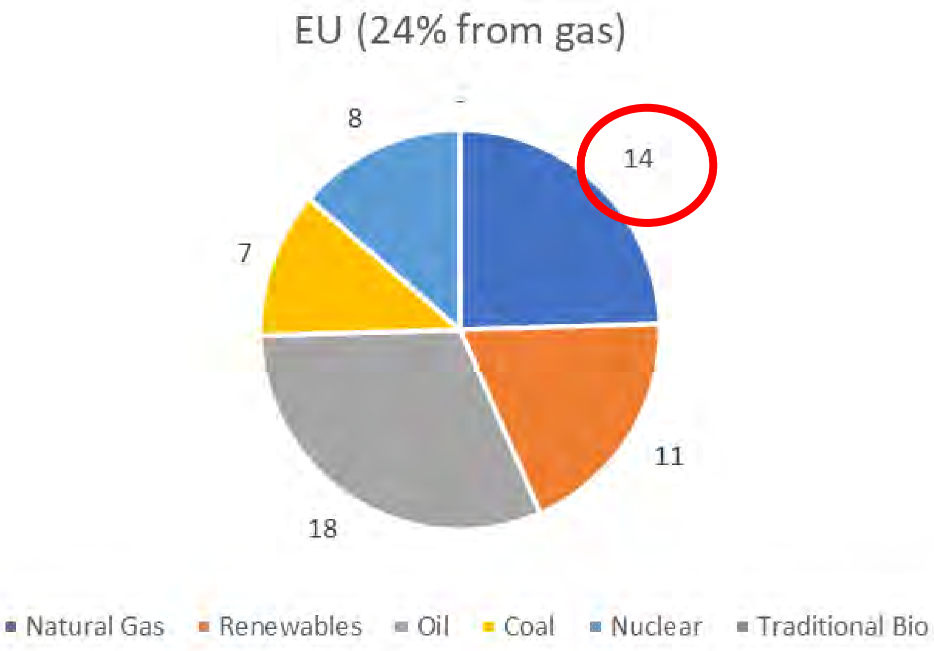
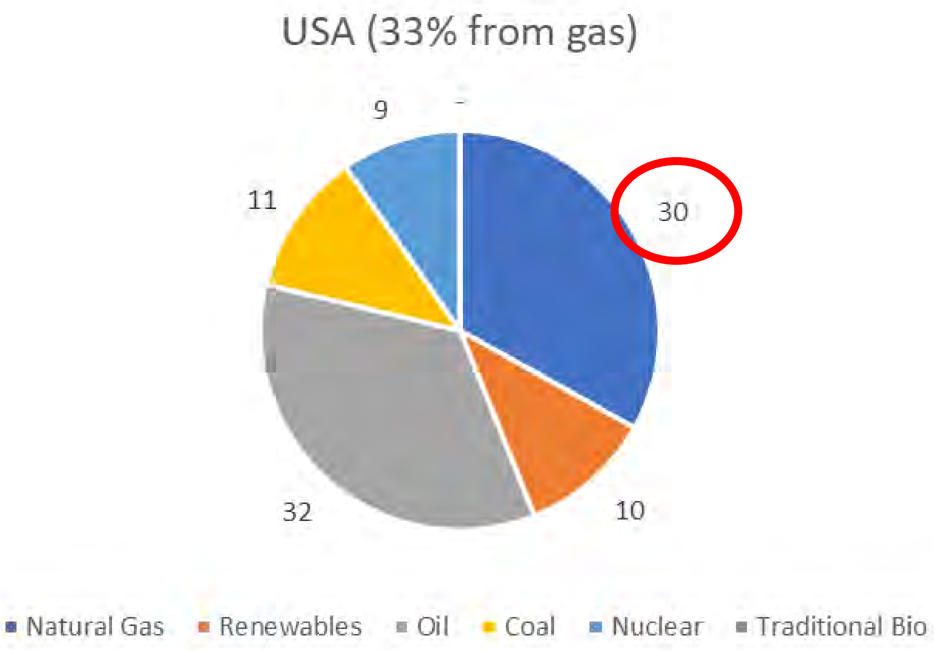
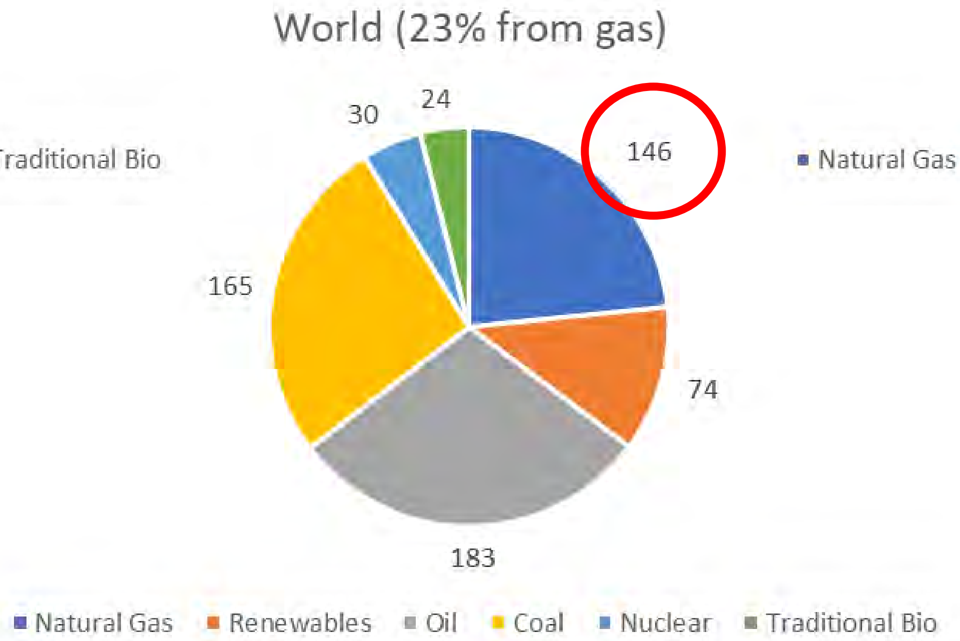
Current (2021) primary energy consumption of gaseous fuels (in exajoules)







Data source: IEA (2022)

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Why do we need renewable gas?

An approach "Decarbonize electricity and electrify everything" – has its limits

Need for renewable hydrocarbons in the form of liquid and gaseous fuels

Heavy-duty, long-distance transport (trucks, ships and planes); high temperature industrial heat (food and beverage sector, steel production, glass production); agriculture (renewable fertilizer such as green ammonia and biofertilizer); and chemical production (such as methanol)

Environmental Science & Technology

POLICY ANALYSIS

pubs.acs.org/est

Contribution of Anaerobic Digesters to Emissions Mitigation and Electricity Generation Under U.S. Climate Policy

David P. M. Zaks,[*,†] Niven Winchester,[‡,§] Christopher J. Kucharik,[†,∥] Carol C. Barford,[†] Sergey Paltsev,[‡] and John M. Reilly[‡]

Environmental Science and Technology, 2011, 45(16): 6735-6742

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Typically, biogas is 50-75% methane. It can be purified to produce renewable natural gas (RNG)

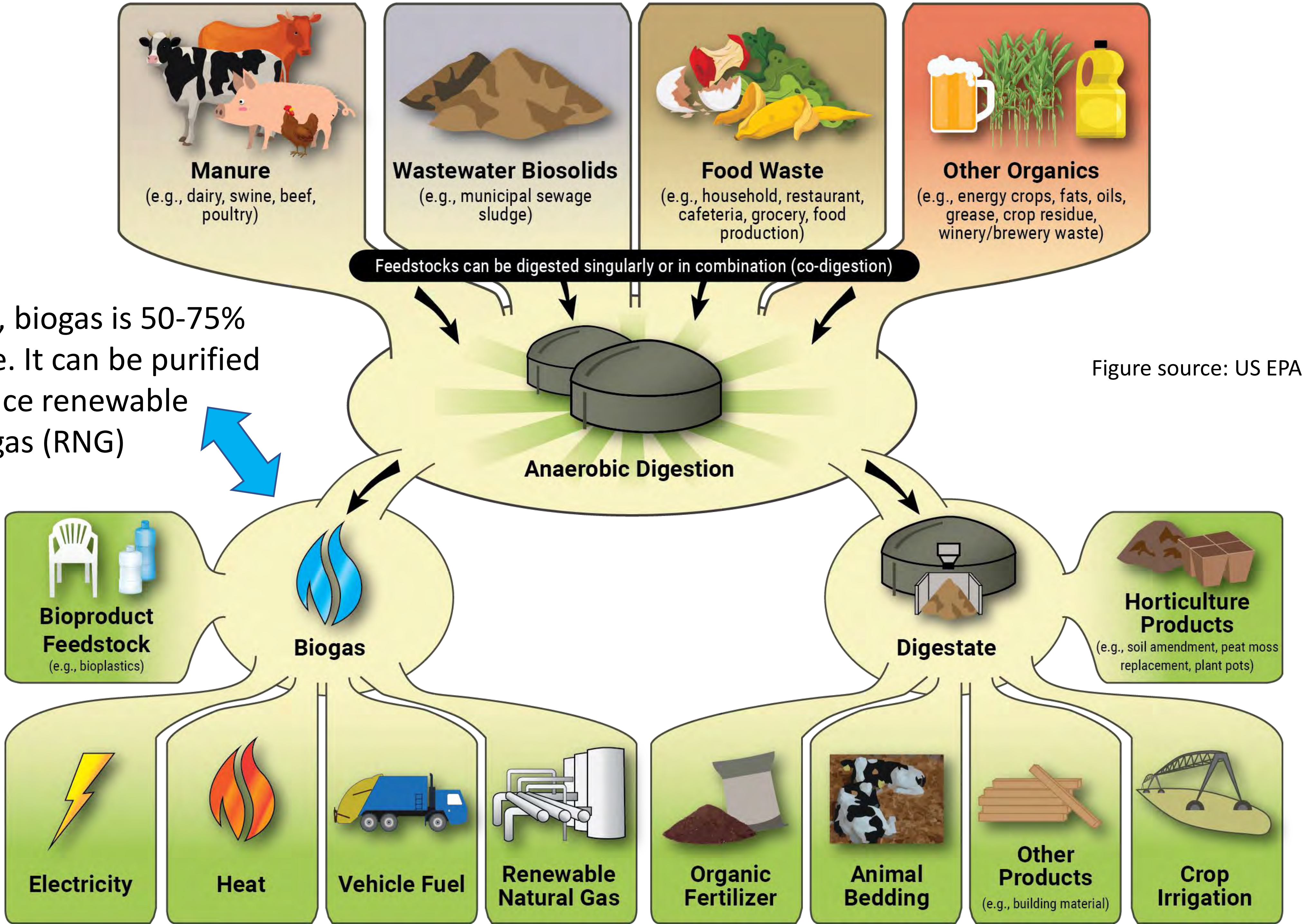

Figure source: US EPA (2023)

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THE COLORS OF HYDROGEN

GREEN

Hydrogen produced by electrolysis of water, using electricity from renewable sources like wind or solar. Zero CO_2 emissions are produced.

BLUE

Hydrogen produced from fossil fuels (i.e., grey, black, or brown hydrogen) where CO_2 is captured and either stored or repurposed.

GREY

Hydrogen extracted from natural gas using steam-methane reforming. This is the most common form of hydrogen production in the world today.

PURPLE/PINK

Hydrogen produced by electrolysis using nuclear power.

TURQUOISE

Hydrogen produced by thermal splitting of methane (methane pyrolysis). Instead of CO_2, solid carbon is produced.

BROWN/BLACK

Hydrogen extracted from coal using gasification.

YELLOW

Hydrogen produced by electrolysis using grid electricity from various sources (i.e., renewables and fossil fuels).

WHITE

Hydrogen produced as a byproduct of industrial processes. Also refers to hydrogen occurring in its (rare) natural form.

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Biomethane and Biogas Benefits and Challenges

Biomethane can be fed into the **existing natural gas infrastructure**

Biogas systems can provide **dispatchable electricity**, production of biogas may be ramped up to provide increased volumes of electricity when demand on the electricity grid is high

A **wide variety of organic feedstocks** such as: municipal or industrial organic waste and wastewater; industry residues (such as stillage); agricultural residues (such as manures and straw); or plant materials

Can create **circular economy** systems within agriculture

Challenge: scale and cost (need for incentives and predictable regulatory framework)

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Green (Low-Carbon-Intensity) Hydrogen Benefits

Potential to provide energy in all parts of economy: industry, transportation, residential.

Potential for remote communities (with no access to grid).

Can be stored in many forms: gas, liquid, solid.

Can be made from various sources.

Zero emissions of carbon during operation, but only as clean as the technology used to produce it.

Typical Assumptions about Hydrogen Production Costs

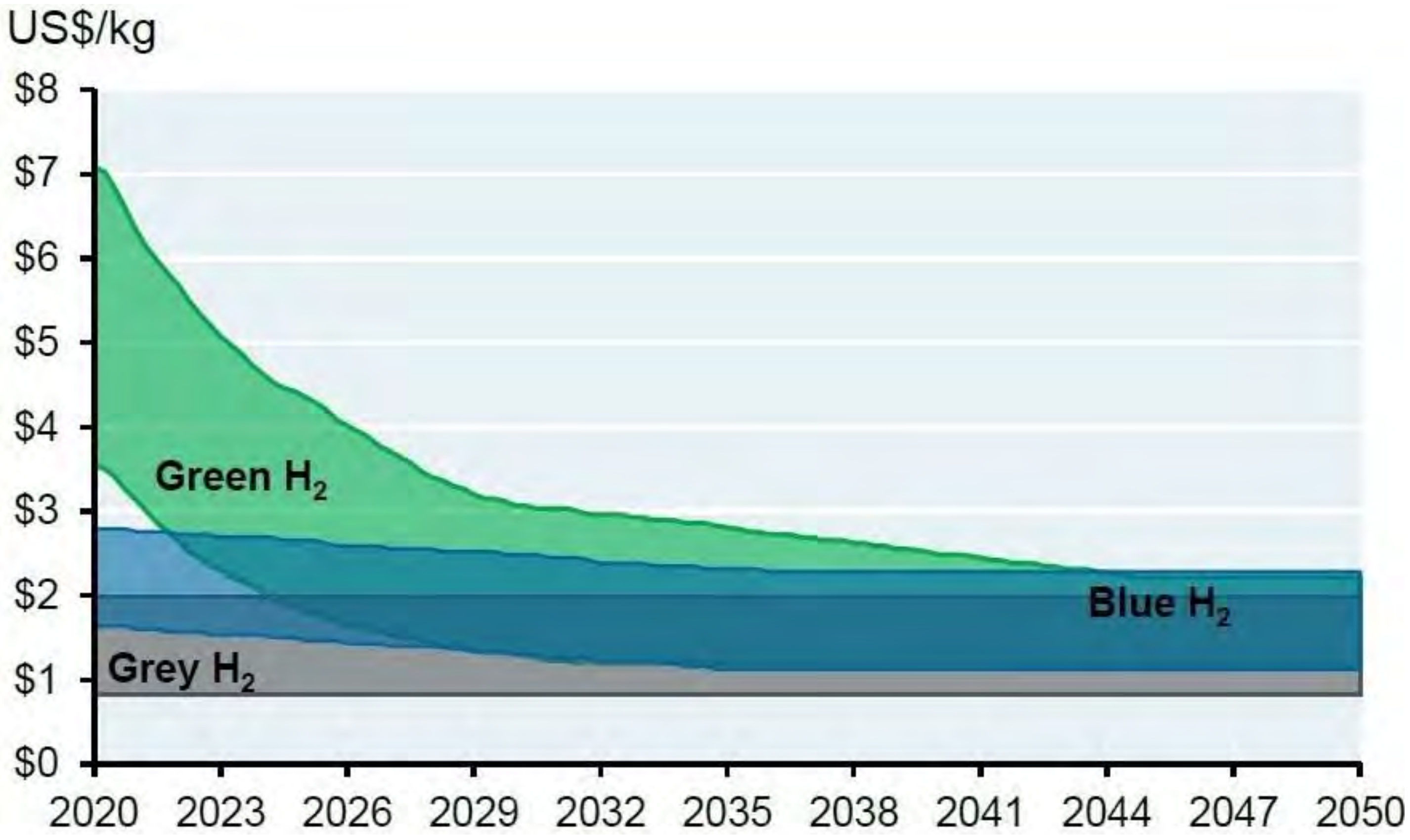


Figure Source: GS (2022)

Typical focus is on **production** costs, but **transportation** and **storage** are also costly

Compare H_2 and NG:

2 \$/kg H_2 = 17.60 \$/MMBTU

4 \$/kgH_2 = 35.10 \$/MMBTU

6 \$/kg H_2 = 52.70 \$/MMBTU

Example: Increased Germany Hydrogen Demand (geopolitics + new climate target)

Earlier study (pre-Feb 2022):

2020 Germany use of natural gas:
90 bcm (2022: 80 bcm; industry is 1/3)

Replace all with H_2: 30 Mt H_2
Need to produce green H_2: 1600 TWh

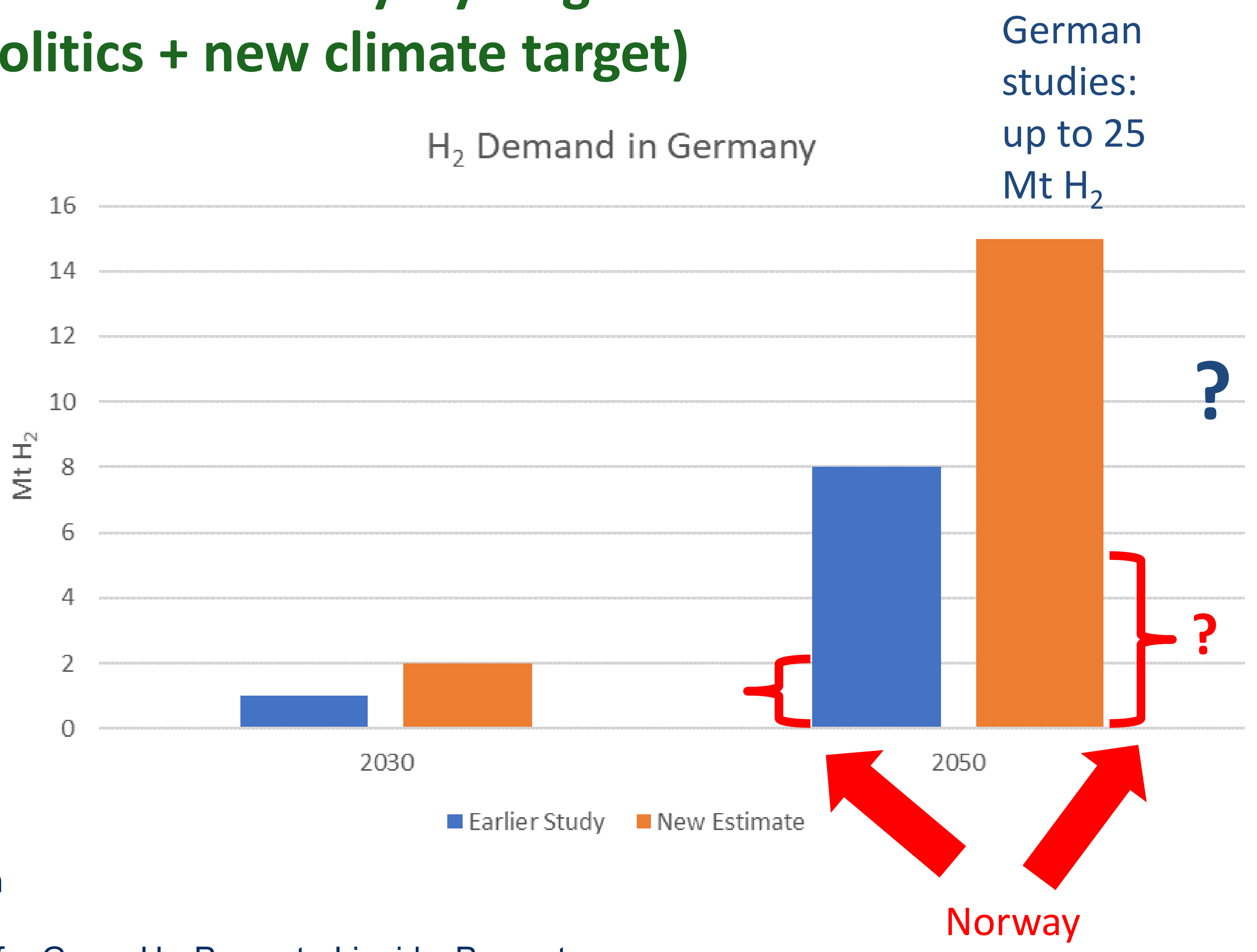
2020 imports from Norway: 30 bcm
2050 imports from Norway: 15 bcm

10 bcm for H_2 production (from Norway) = 2 Mt H_2

4 Mt Green H_2 = 200 TWh
2 Mt H_2 – other gas imports

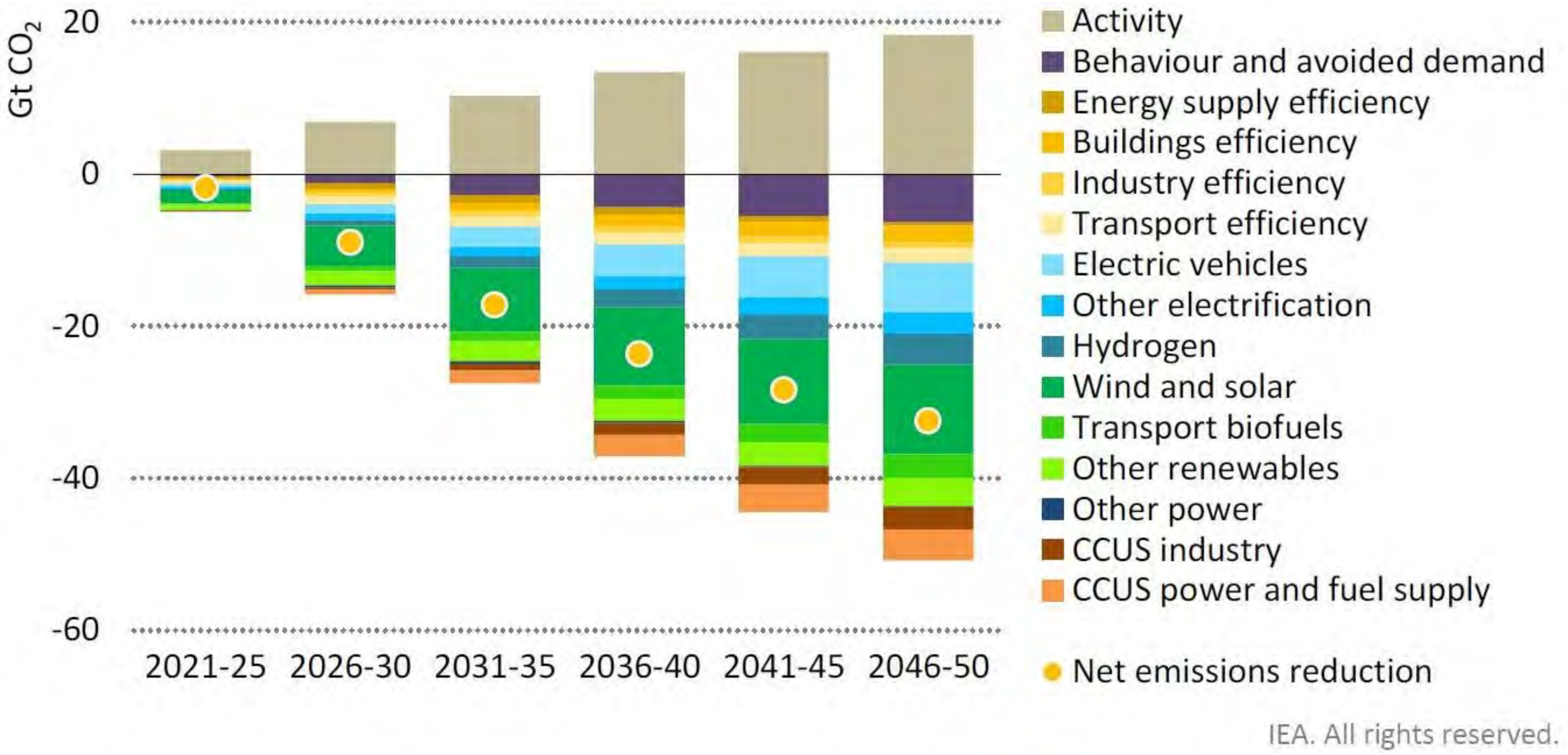
Wind Potential: 300-400 TWh
Solar Potential: 200-300 TWh

Conventional Use of Electricity: 550-600 TWh



Additional Use of Electricity: Electricity needs for Green H_2, Power-to-Liquids, Power-to-Gas could be doubled or tripled depending on technology and demand assumptions

Wide range of measures and technologies are needed



Source: IEA Net Zero by 2050 (2021)

2050 IEA Global Projections (STEPS-NZE)

Final Energy Consumption (i.e., industry, transport, buildings):

Biomethane: 4-7 EJ (1-2% of total final energy consumption)

Hydrogen: 1-21 EJ (0.2-6% of total final energy consumption, 21 EJ = 175 MtH_2)
Ammonia: 0-4 EJ (0-1% of total final energy consumption)
Synthetic Oil: 0-4 EJ (0-1% of total final energy consumption)

Electricity:

Biomethane: ?
Hydrogen: 0-7 EJ (7 EJ = 60 MtH_2)
Ammonia: 0-3 EJ

If all "Green H2", then 12,600 TWh are needed to produce 235 Mt H_2

If ammonia is also from green H_2... add more...

Global Electricity Generation in 2021 was 28,000 TWh

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Thank you

Questions or comments?

Please contact Sergey Paltsev at paltsev@mit.edu

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