Half-baked Methane

Higher Value and Lower Emissions through Pyrolysis

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Program Director

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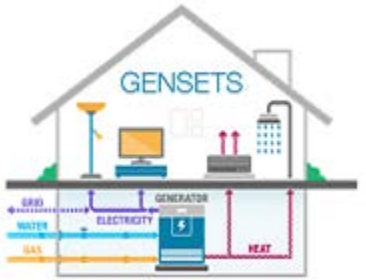
How can we maximize the benefits from U.S. gas wealth?

Existing ARPA-E Nat Gas programs

MOVE

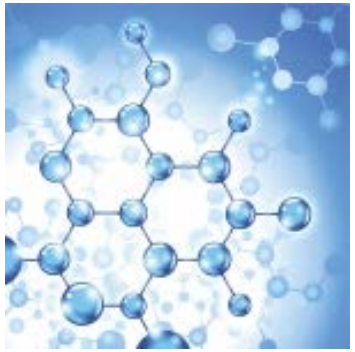
Gas storage tanks and
at-home refueling stations
for passenger cars

GENSETS



Natural gas fueled residential
Combined Heat & Power – **CHP**

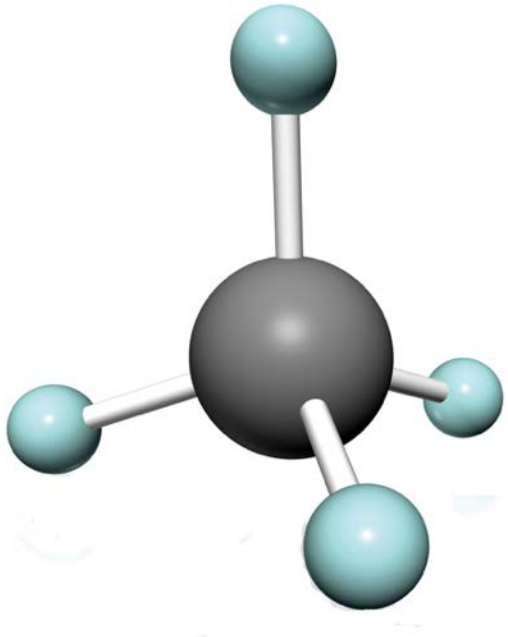
REMOTE



biological Gas-to-Liquid –
bioGTL

- **New Idea:** GTGAS (Gas-to-Gas-and-Solid)

Methane as a hydrogen repository



CH_4

Hydrogen represents

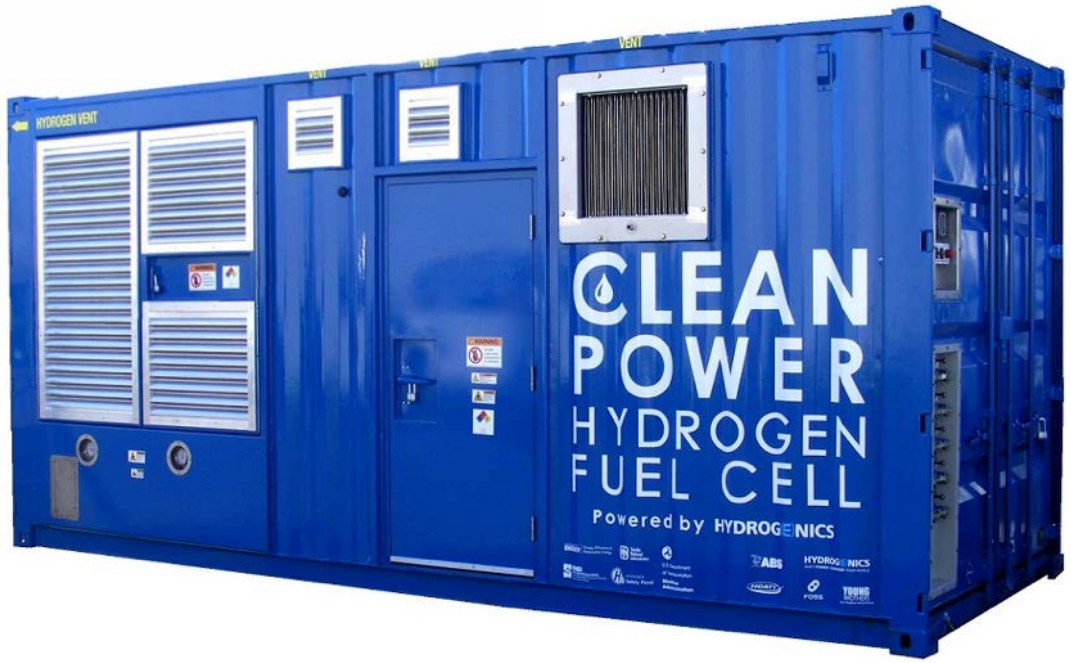
¼ of the **weight**, but

½ of the **energy**

Hydrogen in fuel cells provides very efficient electricity…

…for mobile…

… and stationary applications



We already make Hydrogen from methane at large scale for…

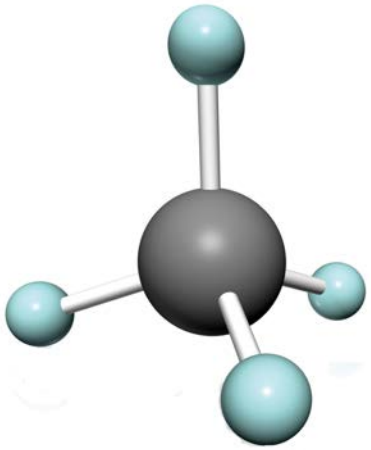
Ammonia Production (Haber-Bosch)

Petroleum Refining

GTL

Challenges: economical only at large scale & CO_2 emissions

Alternative Approach: Thermal Cracking of Methane



1200 - 1400°C

Gaseous hydrogen

+

Solid carbon

$CH_4 \longrightarrow 2\,H_2 + C\,(s)$

CO_2 vs Solid Carbon from 1 Quad of Hydrogen

SMR – CO_2

Image: pbs

70 million MT @1,200 psi
117 million m^3

Methane Cracking – Solid Carbon

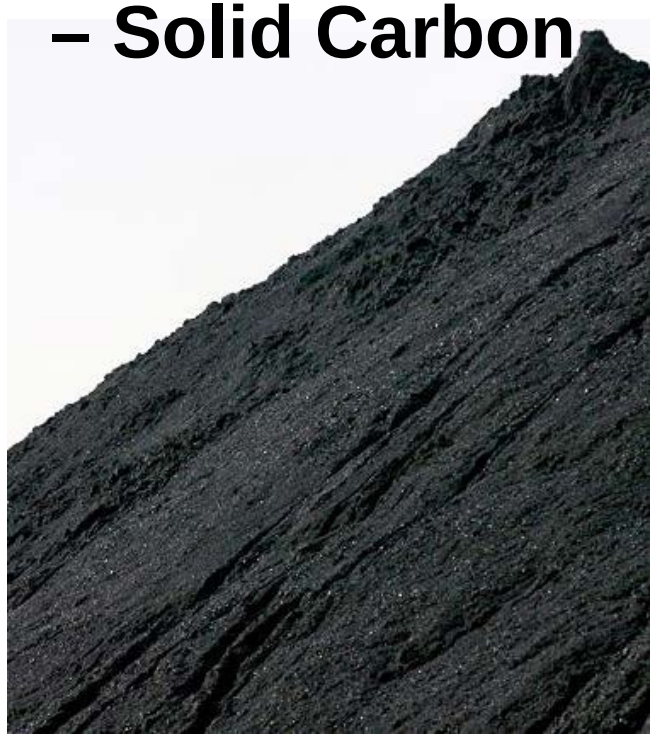


Image: dpa

22.3 million MT
~ 45 million m^3

What's the better value proposition: CO_2 or solid Carbon?

CO_2

Baseline: $0 per ton

Enhanced Oil Recovery: ~ $40/ton

Carbon Capture & Storage: negative $

Solid Carbon

Metallurgical coal: $100/MT

Carbon black: $500-$2,500/MT

Carbon nanotubes: $1,000,000/MT

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CO_2

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Carbon Capture & Storage: negative $

Solid Carbon

Metallu

C /MT

00/MT

>$2,000 per karat
(>$10,000,000/MT)

Not just $$$, but also market size

Total world market:

- Carbon Black: 12 million MT/yr
- Copper: 19 million MT/yr
- Cotton: 24 million MT/yr
- Aluminum: 49 million MT/yr
- Polyolefins: 120 million MT/yr
- Steel: 1,600 million MT/yr
- Concrete: ~20,000 million MT/yr

Remember:
1 Quad H_2 ~ 22.3 million MT C

…but, it's hard to compete with dirt.

Carbon materials could enable low-cost composite buildings

Carbon Fiber Pavilion - Achim Menges

Carbon to building products can be alternative to CO_2 sequestration

Wing House, Asymptote Architecture

One possible path: Methane to CNTs to Carbon Fiber

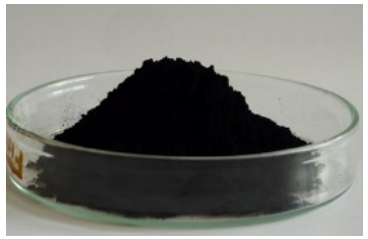
NATURE | VOL 395 | 29 OCTOBER 1998

Synthesis of individual single-walled carbon nanotubes on patterned silicon wafers

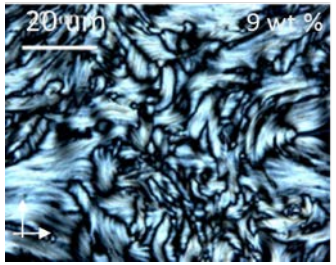
Jing Kong*†, Hyongsok T. Soh†‡, Alan M. Cassell*, Calvin F. Quate‡ & Hongjie Dai*

* Department of Chemistry, ‡ Department of Electrical Engineering,

CNT

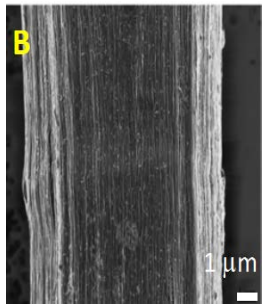


CNT Solution



Fiber spinning

Fibers



RICE

No matter what exact product, the process needs to …

…deliver required product performance targets,…

…provide sufficient yield, and…

…be scalable.

Enabling Technology Developments

Molten Metal Reactor

Photo: Georgia Tech

Computational Fluid Dynamics

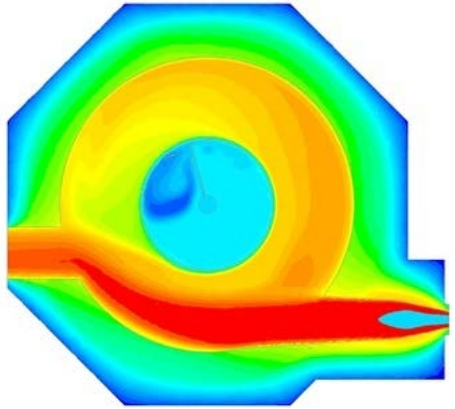
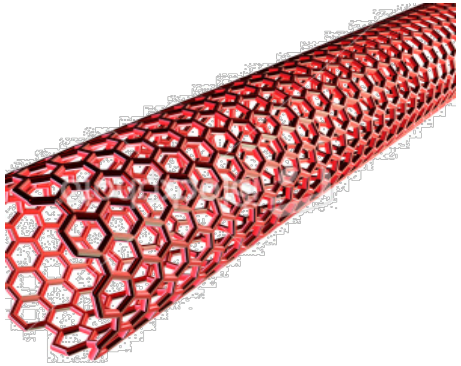


Image:PRETechnologies

Plasma Arc Reactor

Photo:Pyrogenesis

Molecular Modeling



Workshop intended for early Summer ’17…

- …will bringing together experts in:
  - **catalysis**
  - **process engineering**
  - **material science, and**
  - **product/application development**

- …to better define the most promising research and development opportunities to advance methane cracking towards a commercially relevant technology.

- If you are interested, in this topic area, please see me here at the summit or send me an email: **marc.vonkeitz@hq.doe.gov**


Thank you!