

Attachment 2

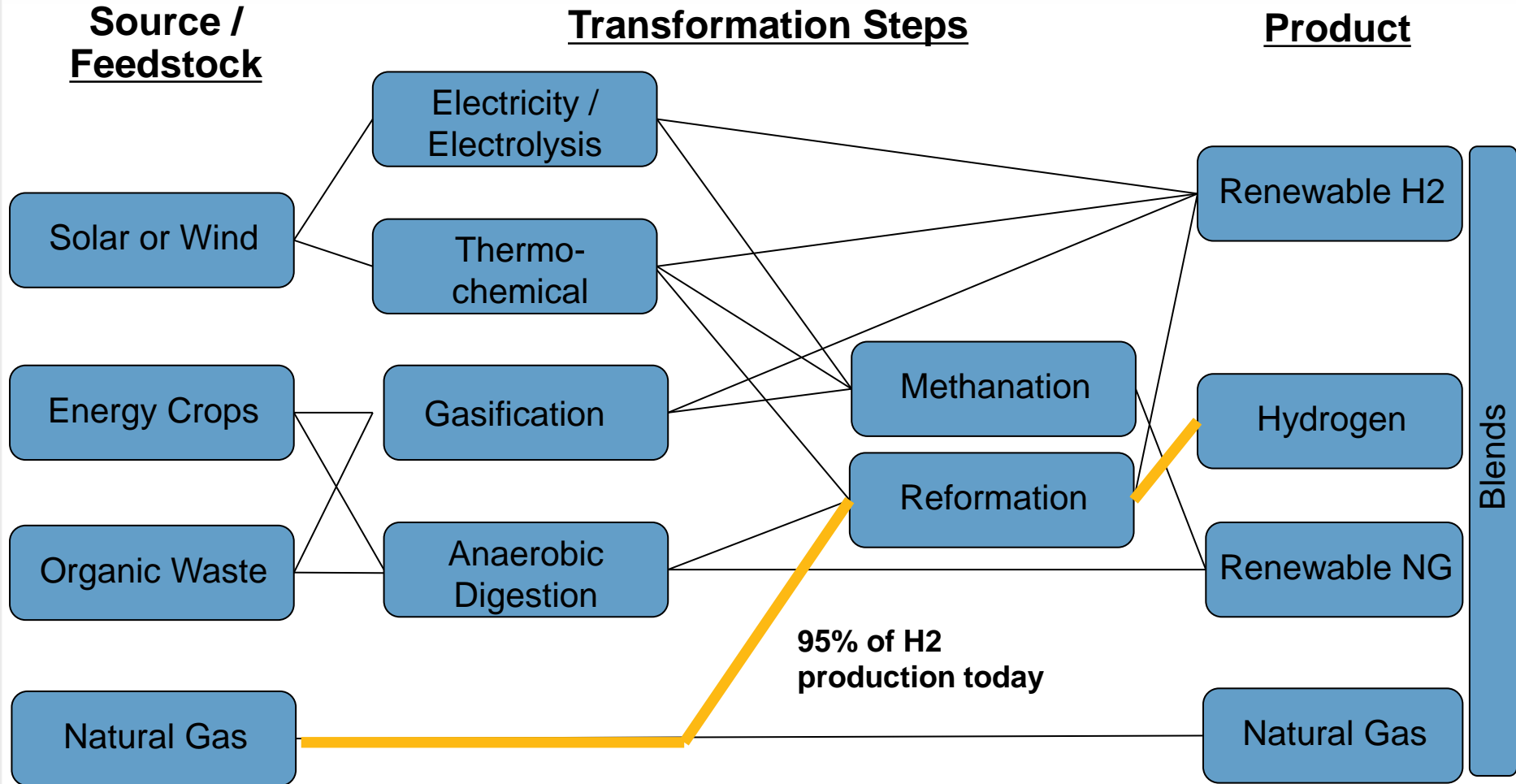
Renewable Natural Gas, Hydrogen and Storage Pathways

April 28, 2014

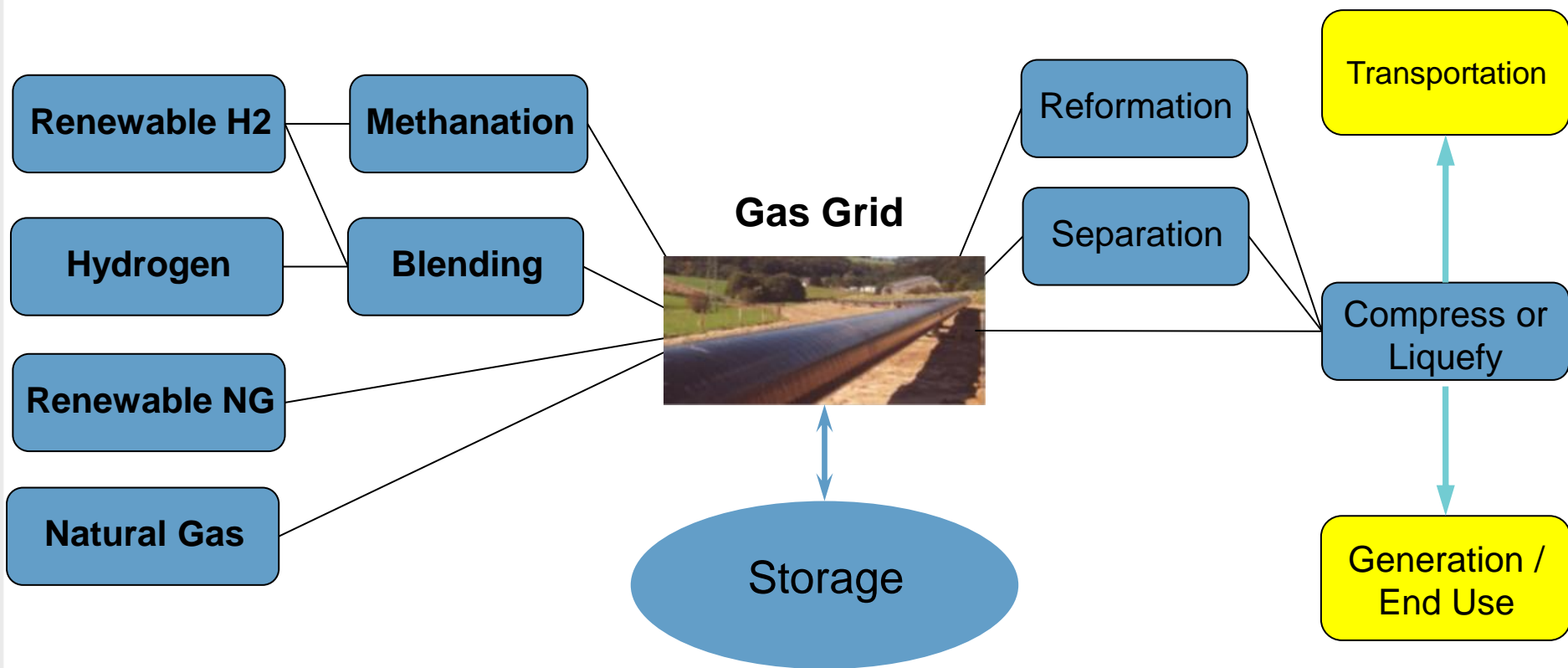
Overview

- SCG has been investigating renewable natural gas and hydrogen technologies for several years
- Due to technical maturity, most effort has been focused on organic waste pathways (anaerobic digestion and landfill)
- Gasification technology is also advancing and is viewed by DoE as the least-cost production pathway for renewable hydrogen in the long term
- Hydrogen-related pathways have become a more significant part of the picture over the past couple of years due to:
 - Impending market introduction of several fuel cell passenger vehicles
 - Recent push in Germany and other European countries to exploit hydrogen as a storage medium along with pressing need for storage in California (Power to Gas)
- Our initial analysis is that Power-to-Gas can be cost competitive with battery storage in bulk storage (load shifting) applications
- Currently exploring opportunities to develop a CA demonstration with members of the California Hydrogen Business Council (CHBC) energy storage committee which we chair

Gaseous Fuel Production Pathways

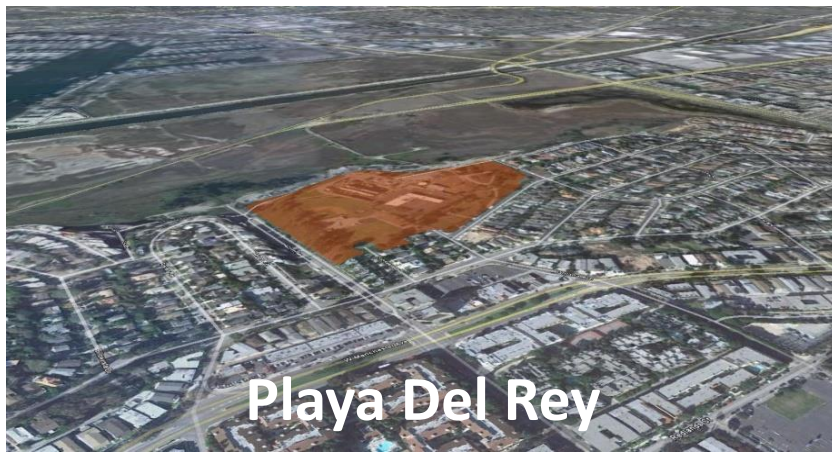
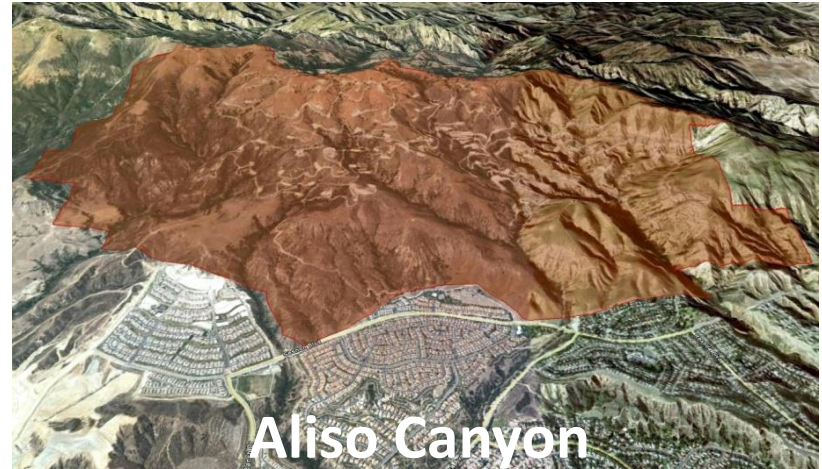


Existing Infrastructure Can Serve Multiple H₂ and CH₄ Pathways



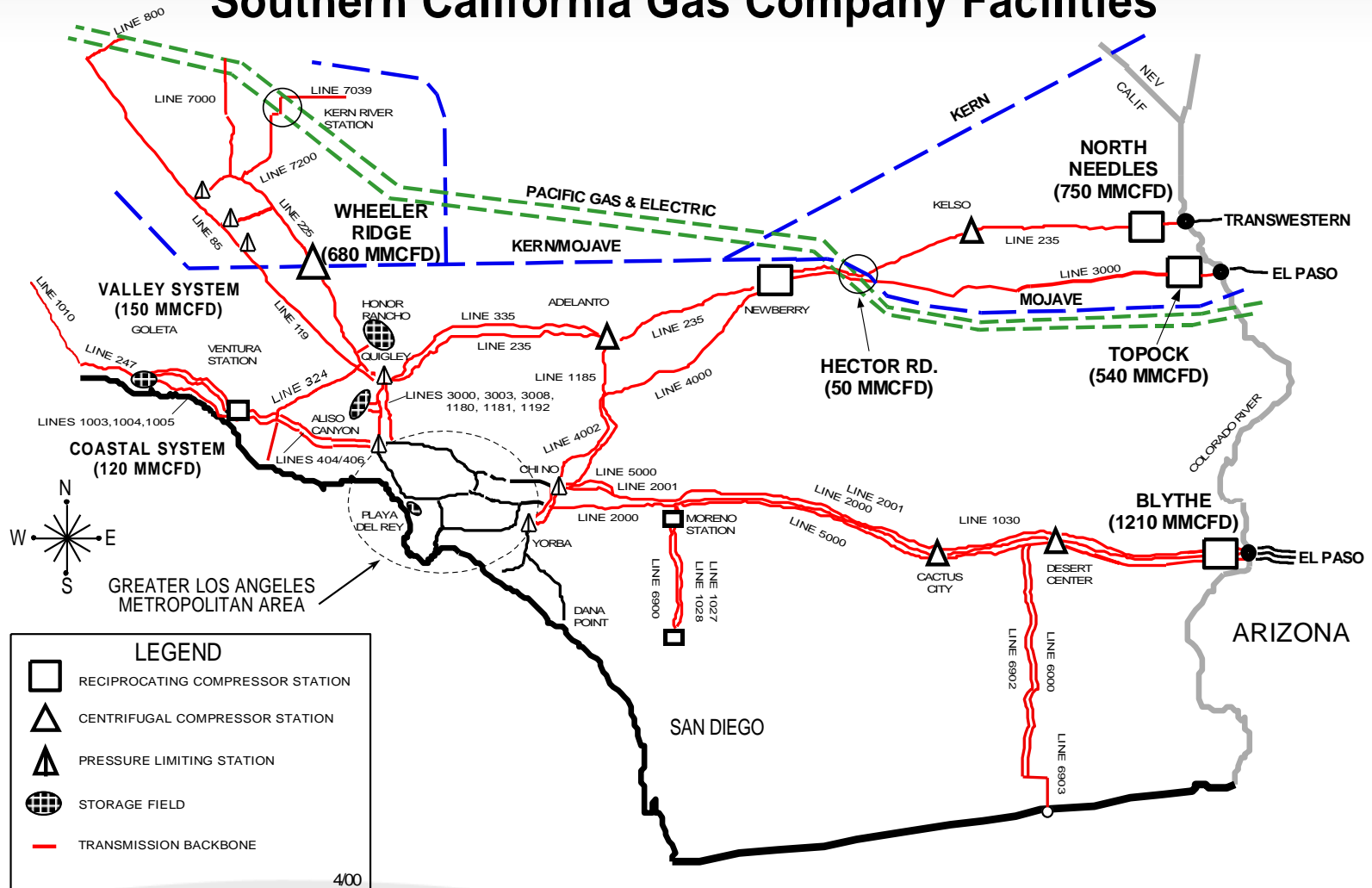
Methane is a Great Storage Medium

SoCalGas' storage fields are the largest energy storage resource in the region



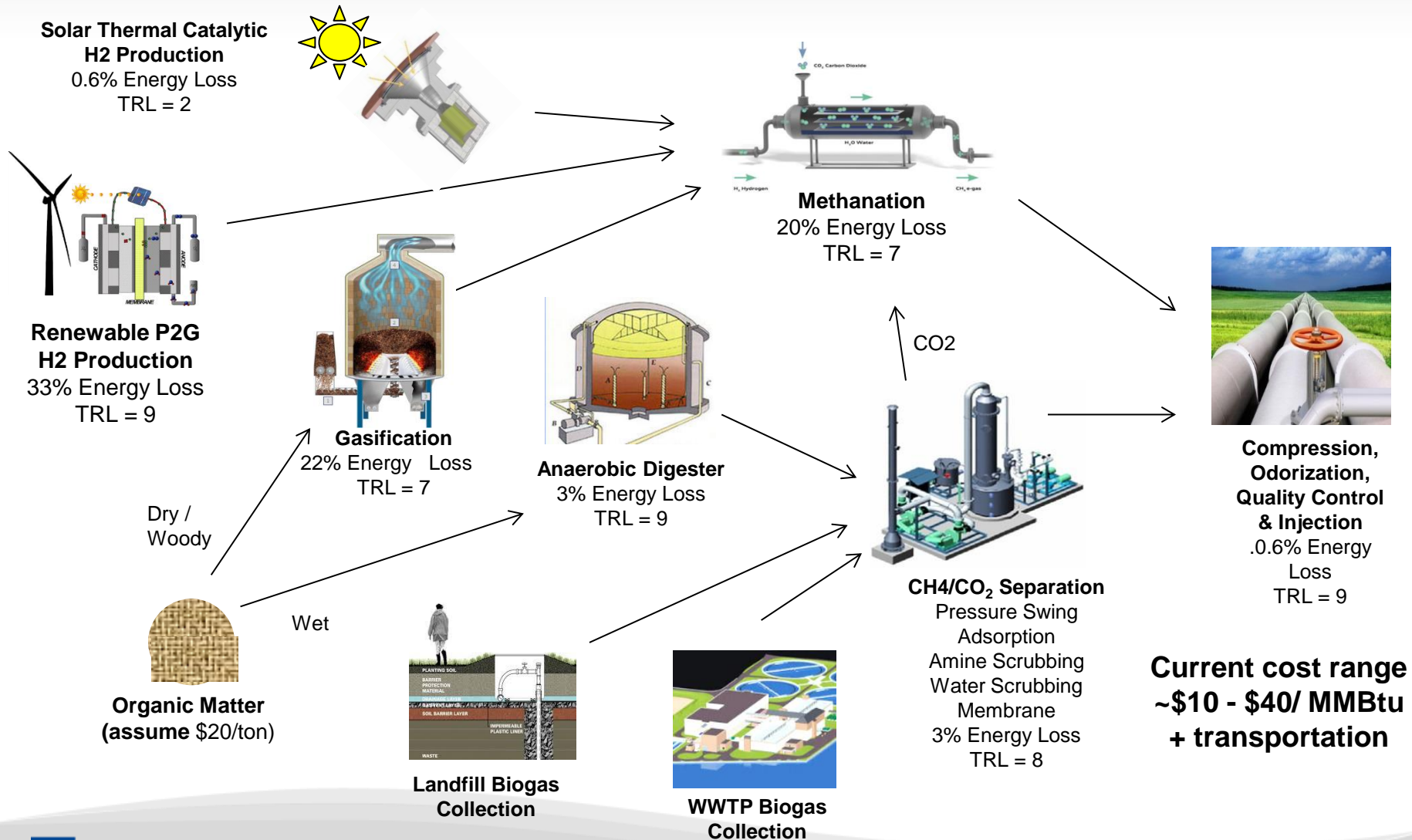
And There's a Fully Built Delivery System

Southern California Gas Company Facilities

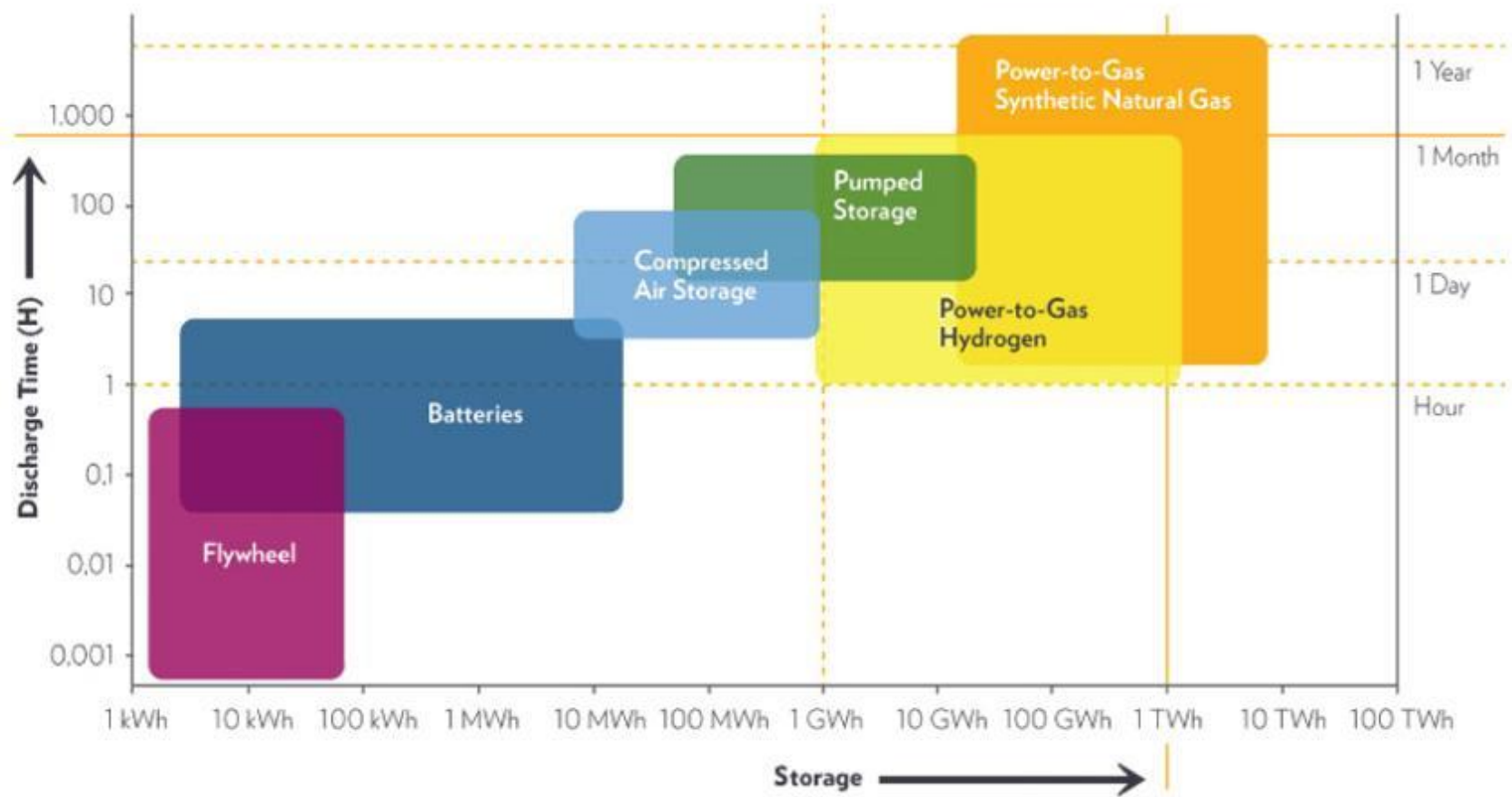


NOT TO SCALE

RNG Pipeline and Storage Pathways



Gaseous fuels provide unique storage functionality



30 Power-to-Gas demonstration projects launched in Europe to date



Power-to-Gas

Audi's Plant (Werlte, Germany)

- Uses PEM electrolyzer to produce H_2 from water
- Methanation process uses CO_2 from biogas plant (2,800 metric tons of CO_2 /yr)
- Produces 1,000 metric tons of e-gas per year



Power-to-Gas

Hydrogenics Plant (Stuttgart, Germany)

- Uses a PEM electrolyzer to produce H₂ from water
- Uses CO₂ from biogas plant
- Produces Methane which is injected into pipeline



Power-to-Gas

2MW Power-to-Gas Demonstration Plant (Falkenhagen, Germany)

- First power-to-gas plant to inject hydrogen into natural gas grid (August 2013)



Electrolysis Technology Companies

PEM Technology

- [Hydrogenics](#)
- [ITM Power](#)
- [Siemens](#)
- [Proton OnSite](#)
- [CETH2](#)
- [Giner, Inc](#)

Alkaline Technology

- [Next Hydrogen Corporation](#)
- [Acta](#)
- [H2 Nitidor](#)
- [McPhy Energy](#)
- [NEL Hydrogen](#)

Methanation Technology Companies

Catalytic

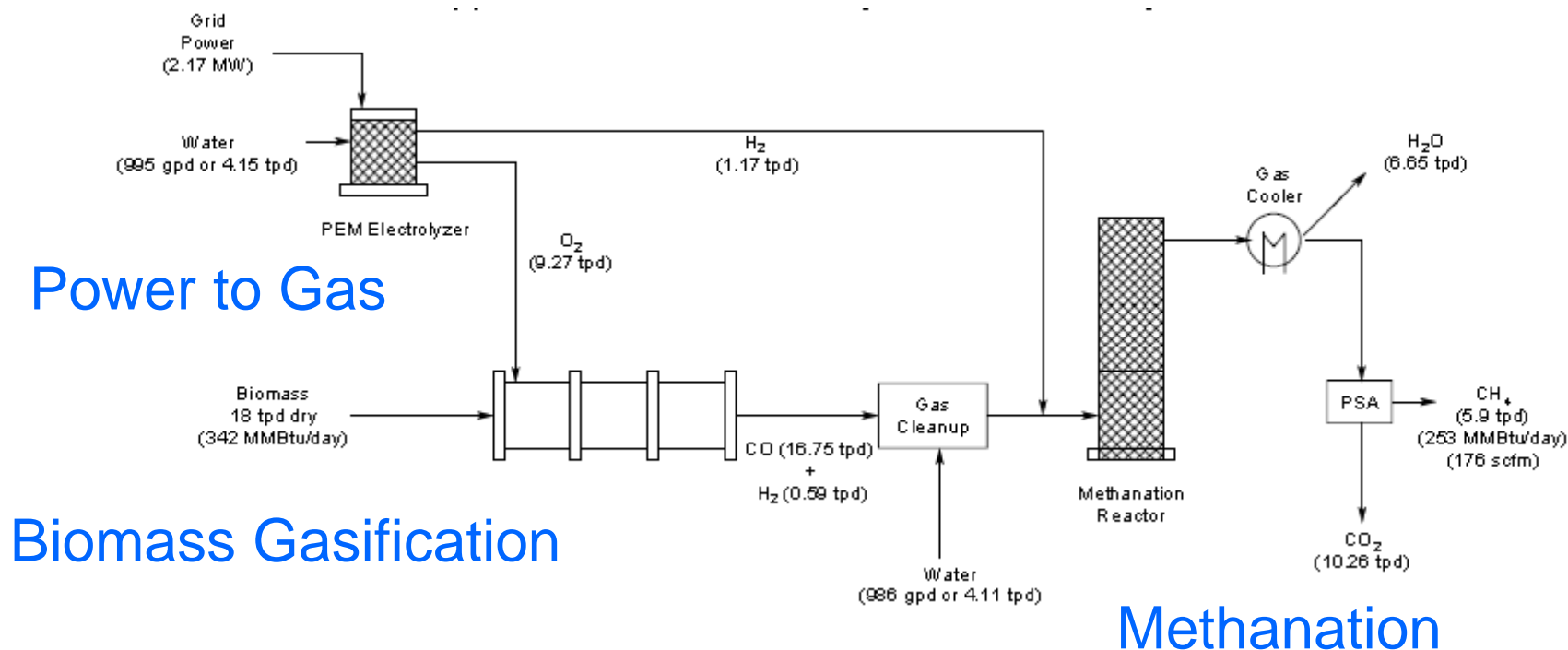
- [Johnson Matthey](#)
- [Haldor Topsoe](#)
- [Clariant](#)

Microbial

- [Electrochaea](#)
- [Tech V](#)
- [Calysta](#)

Power-to-Gas Demonstration Concept

Power-to-Gas Integrated with Biomass Gasification/Methanation



Project cost in the range of \$15M

Additional Slides

Electrolysis Company Details

Company Name	Headquarters	Regions of Operation	Ownership (private/public)	Financials		Core Technologies	Deployed Size
				Revenue	Capitalization		
<u>Fuel Cell Energy</u>	Danbury, CT	USA, Canada, Europe	Publicly Traded	\$196 million	\$635 million	Solid oxide and molten carbonate fuel cell modified for electrolysis	100MW/yr
<u>CETH2</u>	France	-	Private	-	-	PEM Electrolyzers = 200 to 9,600 SCFH Hydrogen production	Not Publicly Available
<u>Giner, Inc</u>	Newton, MA	USA	Private	-	-	PEM Electrolyzers which utilize lower amounts of precious metals, for GM and Navy	6 Oxygen Generation plant & 28 Low pressure electrolyzers
<u>Hydrogenics GmbH</u>	Gladbeck, Germany	USA, Canada, Europe, & Asia.	Publically Traded	\$42 million	\$265 million	Water splitting Alkaline (HySTAT) and PEM (HyLYZER) electrolyzers	Presence on every continent, except antartica
<u>ITM Power Inc.</u>	Sheffield, UK	Europe & North America	Publically Traded	\$1.2 million	\$84 million	Fast response PEM electrolyzer = 3.5-13.5 kW	\$105,000 sold in 2013 & \$750,000 sold in 2012
<u>Proton OnSite</u>	Wallingford, CT	USA	Private	-	-	Water splitting PEM Electolyzer for on-site vehicle H2 generation	Not Publicly Available
<u>Siemens</u>	Germany	Worldwide	Publicly Traded	\$97.47 billion	\$111.59 billion	120 kW PEM electrolyzer for naval submarines	Not Publicly Available
<u>Next Hydrogen</u>	Mississauga, ON	-	Private	-	-	New Alkaline electrolyzer design	Not Publicly Available
<u>Acta S.p.A</u>	Italy	Germany, Hawaii, Australia, Japan	Publicly Traded	\$550,000	\$13.8 million	Alkaline electrode membrane electrolyzers, fuel cell systems, catalysts	Not Publicly Available
<u>H2 Nitidor Srl</u>	Italy	Europe	Private	-	-	High-pressure alkaline water electrolyzers	Not Publicly Available
<u>McPhy Energy SA</u>	France	Europe	Private	-	-	Water electrolyzers in skid or container form, Solid hydrogen storage using metal hydrides	Not Publicly Available
<u>NEL Hydrogen AS</u>	Notodden, Norway	South America, Asia, South Africa, Europe	Private	-	-	NEL A solid-oxide water electrolyzer	Not Publicly Available

Methanation Company Details

Company Name	Headquarters	Regions of Operation	Ownership (private/public)	Financials		Core Technologies	Deployed Size
				Revenue	Capitalization		
<u>Johnson Matthey</u>	London, UK	Europe, Asia, & North America	Publicly Traded	\$12.25 billion	\$6.36 billion	Process technology and catalysts for the production of bio-SNG	-
<u>Haldor Topsoe</u>	Texas, USA	Europe, Asia, Africa, and North & South America	Publicly Traded	\$944 million	-	Methanation catalysts	-
<u>Clariant</u>	Muttenz, Switzerland	Europe and North America	Publicly Traded	\$6.51 billion	\$6.44 billion	Catalysts for use in the manufacture of hydrogen and synthetic natural gas	-
<u>Electrochaeta</u>	Denmark	Denmark & North America	Private	-	-	Microbes that work as biocatalysts, and reactors optimized for biocatalytic methanation	ForskEL demonstration project = 0.02-0.21 MMBTU/Hr biogas
Tech V	Sioux Falls, SD	-	Private	-	-	Uses a low temp./pres. biological technology to convert biomass or a syngas stream into methane	-

Power to Gas Projects in Europe

	Project	Installed power (kW)	Electrolysis technique	Methanation principle	Application	Power load
1	Werlte (D) – Audi AG	6.000	Alkaline	Chemical	Gas grid - mobility	Base load
2	Aragon (S) – IThER	4.000 + 70	Alkaline + PEM	n/a	Mobility	unknown
3	Falkenhagen (D) – E.ON AG	2.000	PEM	n/a		Flexible load
4	Puglia region (I) – INGRID Project	1.200	Alkaline	n/a	Gas grid	Flexible
5	Grapzow (D) – RH ₂ WIND Project Gruppe	1.000	Alkaline	n/a	CHP & gas grid	Flexible
6	Graben (D)	1.000	unknown	Chemical	Gas grid	unknown
7	Sudenburg (D) – Greenpeace Energy (& Gasunie) <i>Canceled</i>	1.000	Alkaline	n/a	Gas grid	unknown
8	Hamburg (D) – Vattenfall	900	Alkaline	n/a	Mobility	Base load
9	Prenzlau (D) – Enetrag AG	500	Alkaline	n/a		Base load
10	Frankfurt (D) – Thuga & ITM Power	360	PEM	n/a	Gas grid	Flexible load
11	Foulum (DK) Electrochaea	250	PEM	Biological	Gas grid	Flexible load
12	Stuttgart (D) – Solar Fuel & Fraunhofer IWES	250	PEM	Chemical	Gas grid	unknown
13	Karlsruhe (D) – DVGW & KIT	200	unknown	Chemical	Gas grid	unknown
14	Xermade (S) - Sotavento Project	200	Alkaline	n/a	Engine	Flexible load
15	Herten (D) – Stadt Herten & Evonic Industries	165	PEM	n/a	Mobility	unknown
16	Leverkusen (D) – CO2RRECT Project: Siemens & RWE	100	unknown	unknown	unknown	unknown
17	Schwandorf (D) – Eucolino: Schmack & Viessmann	100	unknown	Biological	Gas grid	unknown
18	Ibbenburen (D) – RWE, CERAM Hyd	100	unknown	unknown	Gas grid	unknown
19	Utsira (N)	50	Alkaline	n/a	Fuel cell & hydrogen turbine	unknown
20	Freiburg (D) – H2Move: Fraunhofer ISE	40	unknown	unknown	unknown	unknown

Power to Gas Projects in Europe (cont'd)

	Project	Installed power (kW)	Electrolysis technique	Methanation principle	Application	Power load
21	Tahivilla (S) – Hidrolica Project	40	PEM	n/a	Fuel cell	Flexible load
22	Stuttgart (D) – Solar Fuel & Fraunhofer ZWS	25	PEM	Chemical	Gas grid	Flexible load
23	SamsØ (DK) – SamsØ Energy Academy	20	unknown	unknown	unknown	unknown
24	Groningen (NL) – DNV KEMA	7	PEM	Chemical	Gas grid	Base load
25	Berlin (D)	6	unknown	unknown	Gas grid	unknown
26	Rostock (D) – WTI	3	unknown	unknown	Mobility / fuel	unknown
27	Dortmund (D) - DWE & DBI	N/A	unknown	unknown	unknown	unknown
28	Copenhagen (DK) – Haldor Topsoe	N/A	unknown	unknown	unknown	unknown
29	Augsburg (D) – Erdgas Schwaben: Solar Fuel, GASAG & Thuga	N/A	unknown	Chemical	unknown	unknown
30	France (GRHYD) - GdF, GRdF, Areva, GNVert, etc.	N/A	unknown	unknown	Mobility & gas grid	Flexible

Hydrogen & Methanation

Hydrogen as an energy currency is uniquely capable of swinging between power, chemical and transportation markets

