Delivering Renewable Hydrogen Infrastructure

Scotland's Hydrogen Future

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Infrastructure Discussion

- Today's state of affairs
- The next few years
- Longer term
- Indian market

Infrastructure

The term *infrastructure* has been used since 1927 to refer collectively to the roads, bridges, rail lines, power grids, gas networks and similar **public works that are required for an industrial economy, or a *portion* of it, to *function*.**

Today's state of affairs

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Air Products Focused on Energy

- Clean energy
- Non-conventional oil and gas
- Industrial gases for refining
- Power generation

Air Products
50+ years of hydrogen experience

- Over 5000MT per day H_2 production
- Bulk, liquid, and pipeline distribution
- World's largest H2 producer
- H_2 energy projects since 1993
  - > 100 hydrogen stns
  - > 100,000 fuelings/yr
- Stations in 16 countries
- Active in UK hydrogen arena
  - via UKHA, CENEX & SHFCA
- Active in Europe
  - via the JTI and the EHA

Today's state of affairs

Real advances are being made

Applications that transition to hydrogen, and deliver value today

- Fuel Cell Vehicles
- Mass transit/central fleets
- Material handling networks
- Back-up/stationary power
- Renewable Energy Parks

Today's state of affairs

Retail-like fueling experience

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Hydrogen stations

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Infrastructure Transition

- Provide technologies which have utility today while positioning for the future
- Focus on a regional model with abundant H2 and population.
- Focus on mass transit in other urban areas.
- ☆ *Future Hydrogen Infrastructure will include:*
  - *Pipeline delivered hydrogen similar to NG*
  - *Multiple feed sources of hydrogen from:*
    - *Biomass*
    - *Geothermal*
    - *Wind*
    - *Solar*
    - *Nuclear*
    - *Coal*
    - *Methane reforming*
  - *Delivered or distributed product in the outlying areas*

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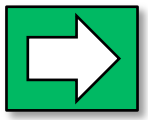
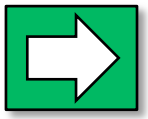
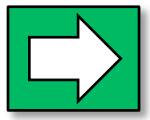
Renewable hydrogen is a must

- Status quo is not an option
- Air Products is committed to collaborative programs focused on renewable hydrogen

Longer term







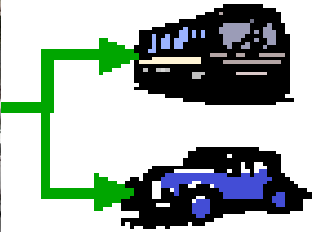
Wind and Solar to Hydrogen

Power Conditioning

Grid

Electrolyser

FC or ICE



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Wind to Hydrogen

- GAS NATURAL: Sotavento wind farm (60 Nm^3/h H_2 production)

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PV to hydrogen

- Hércules project (Spain)
- Located at the site of a solar collector facility
- Transport application
- converting a diesel car into a hybrid
- 8 companies participating, including Air Products

Acknowledgements:
Agencia de Innovación y Desarrollo de Andalucía (IDEA), and
Ministerio de Educación y Ciencia,
both for their financial support

Hercules

ExpoZaragoza, Spain

- Three months Expo held in Summer 08 with theme of ‘Water and Sustainable Development’
- Air Products installed an electrolyser, hydrogen storage and dispensing (200 bar and 350 bar)
- First public hydrogen fuelling station in Spain

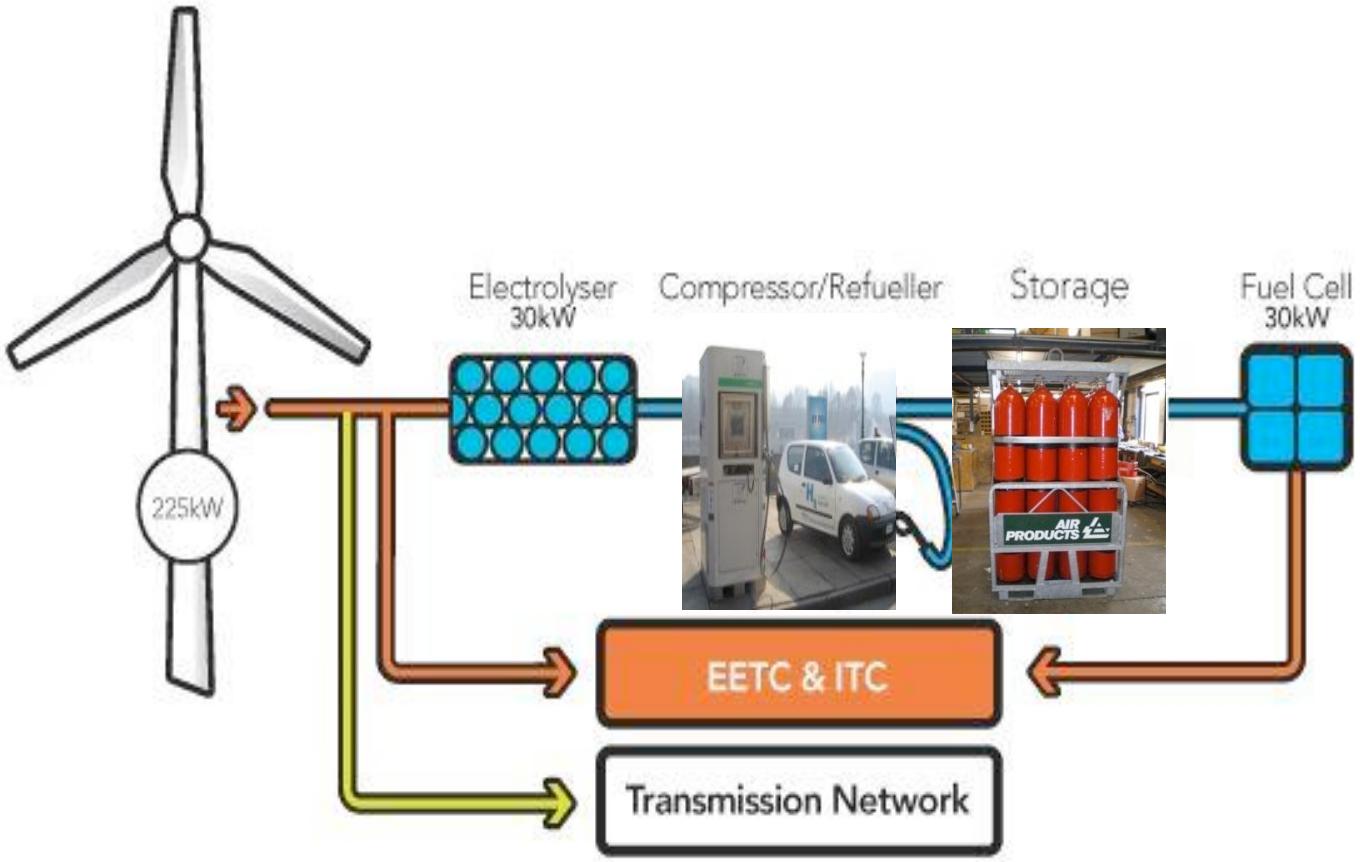
Designed to be permanent and will be infrastructure legacy after the Exposition is completed

TfL, London Bus Supply

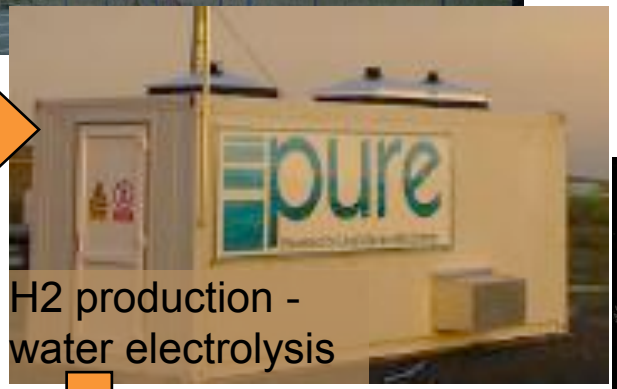
- Onstream late 2010
- Fuelling of up to 10 buses for 5 years
- LHY supply via a novel supply concept trailer

Hydrogen Mini Grid Rotherham

- **AP have supplied an S100 hydrogen fuelling system + green hydrogen store for Hydrogen Mini Grid**
- **Funded by Yorkshire Forward as part of the Objective 1 investment programme**



Hebridean Hydrogen Park H2seed



Storage

Fuelling station

Production: 5Nm^3/h

Storage (buffer): ~22Nm^3 at 30 bar

Storage (high pressure): ~65Nm^3 at 420 bar

Application

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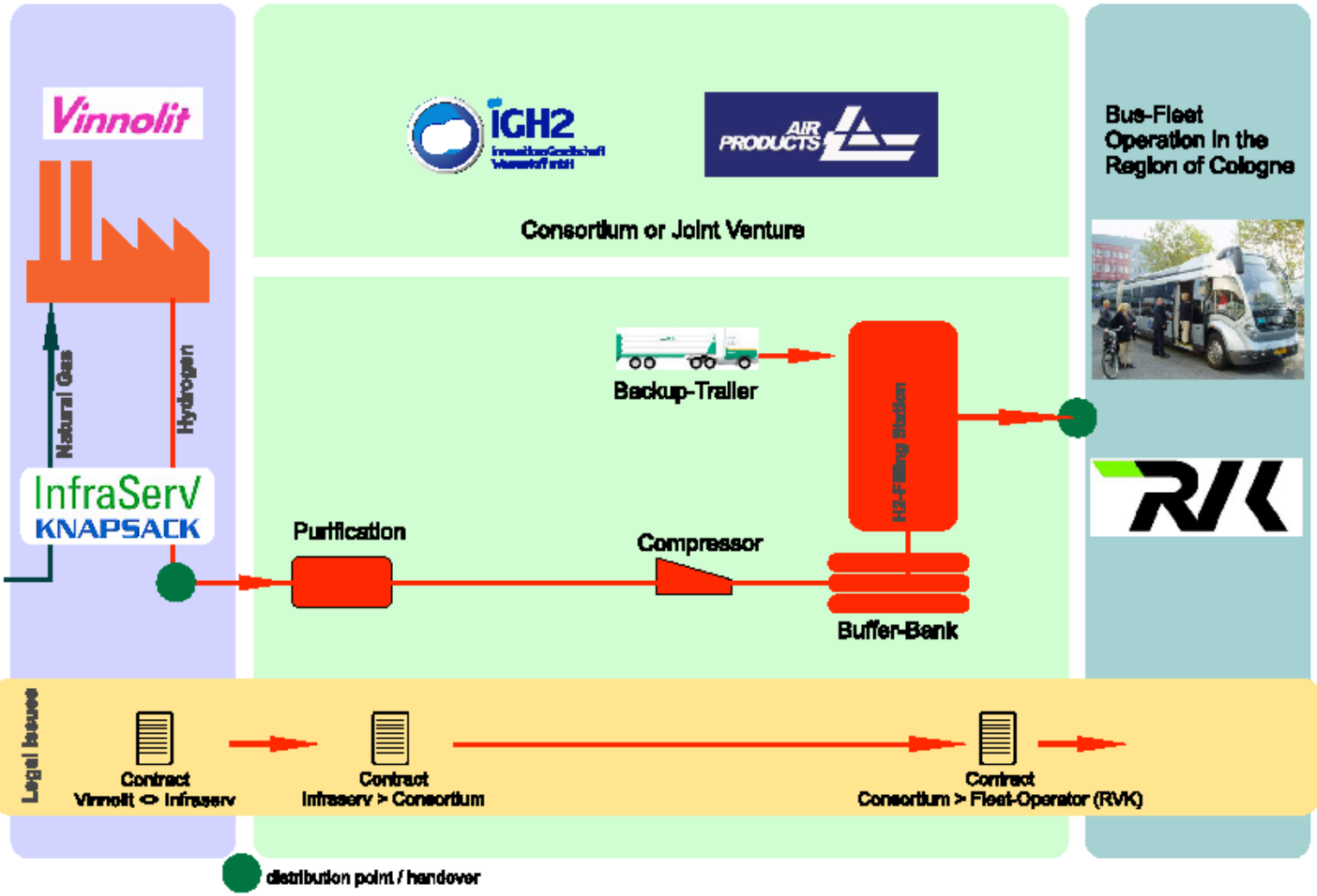
Hürth Bus Project Organisation



So what do Air Products know about bio methane?

- Gas separation experience
- R&D, IP
- Prism®, Gemini®
- Other technologies
- World's Broadest Portfolio of Pressure, Vacuum, and Temperature Swing Adsorption Products

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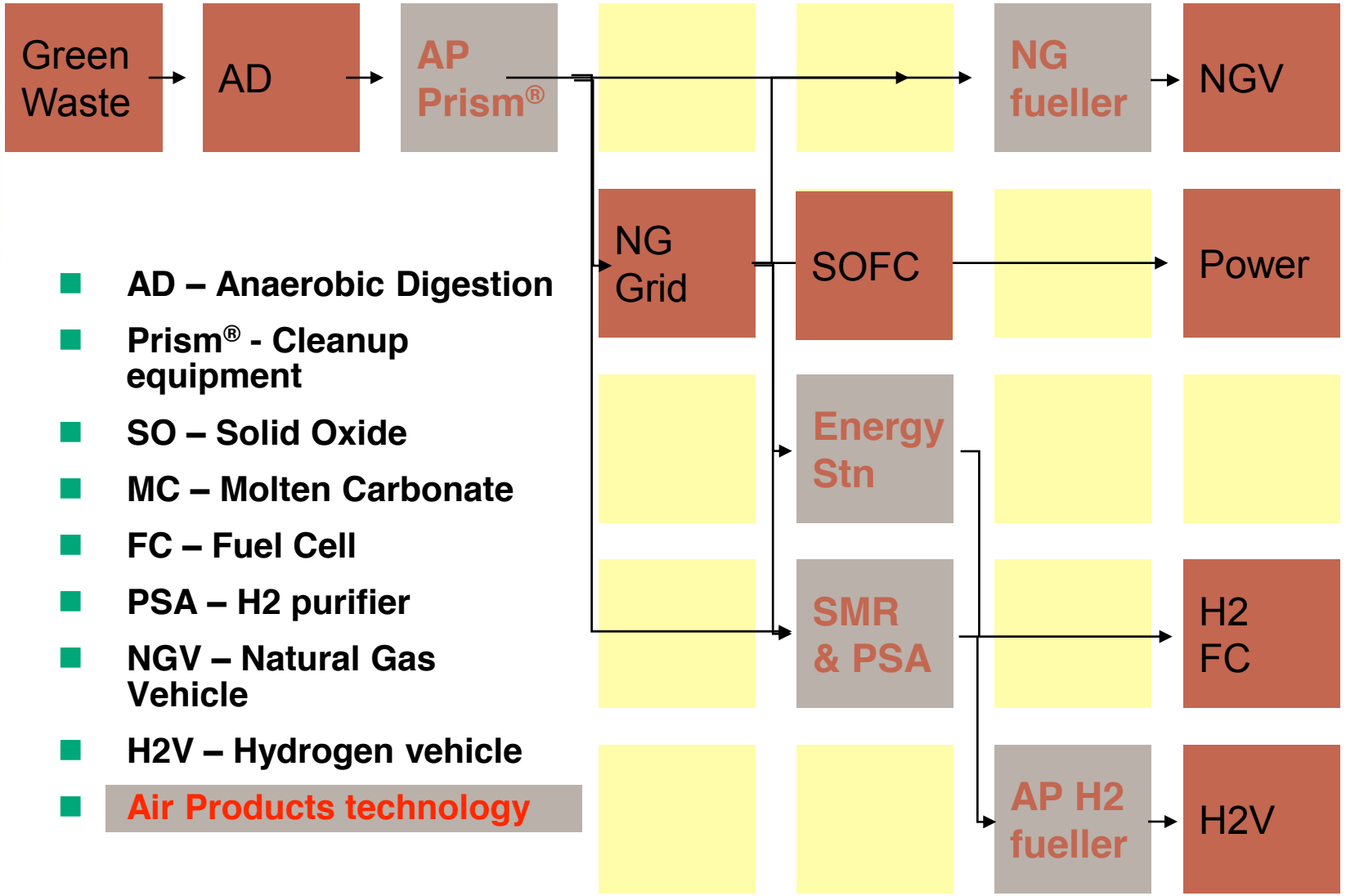
Waste to Energy Options



- AD – Anaerobic Digestion
- Prism® - Cleanup equipment
- SO – Solid Oxide
- MC – Molten Carbonate
- FC – Fuel Cell
- PSA – H2 purifier
- NGV – Natural Gas Vehicle
- H2V – Hydrogen vehicle
- Air Products technology

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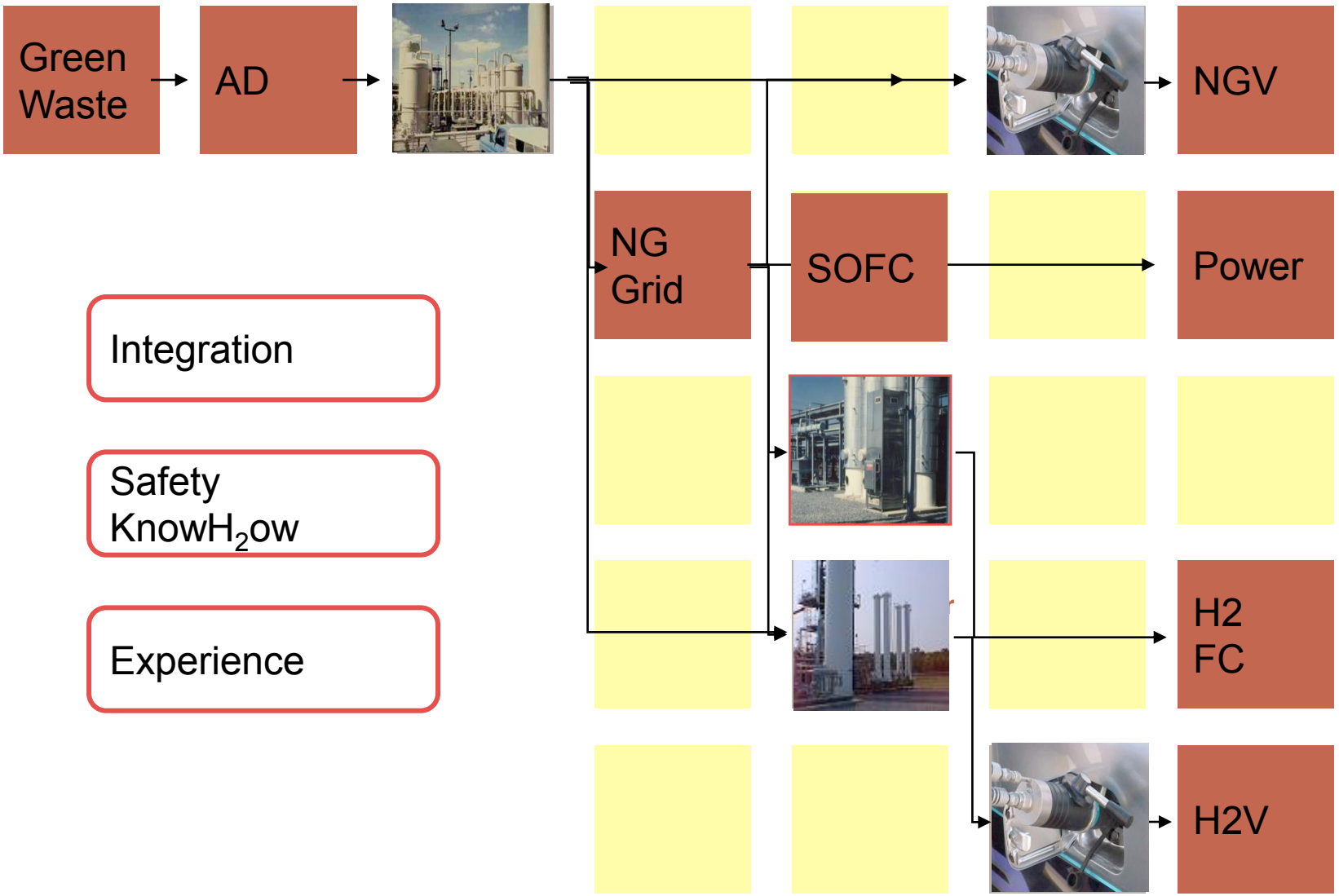
Waste to Energy Options

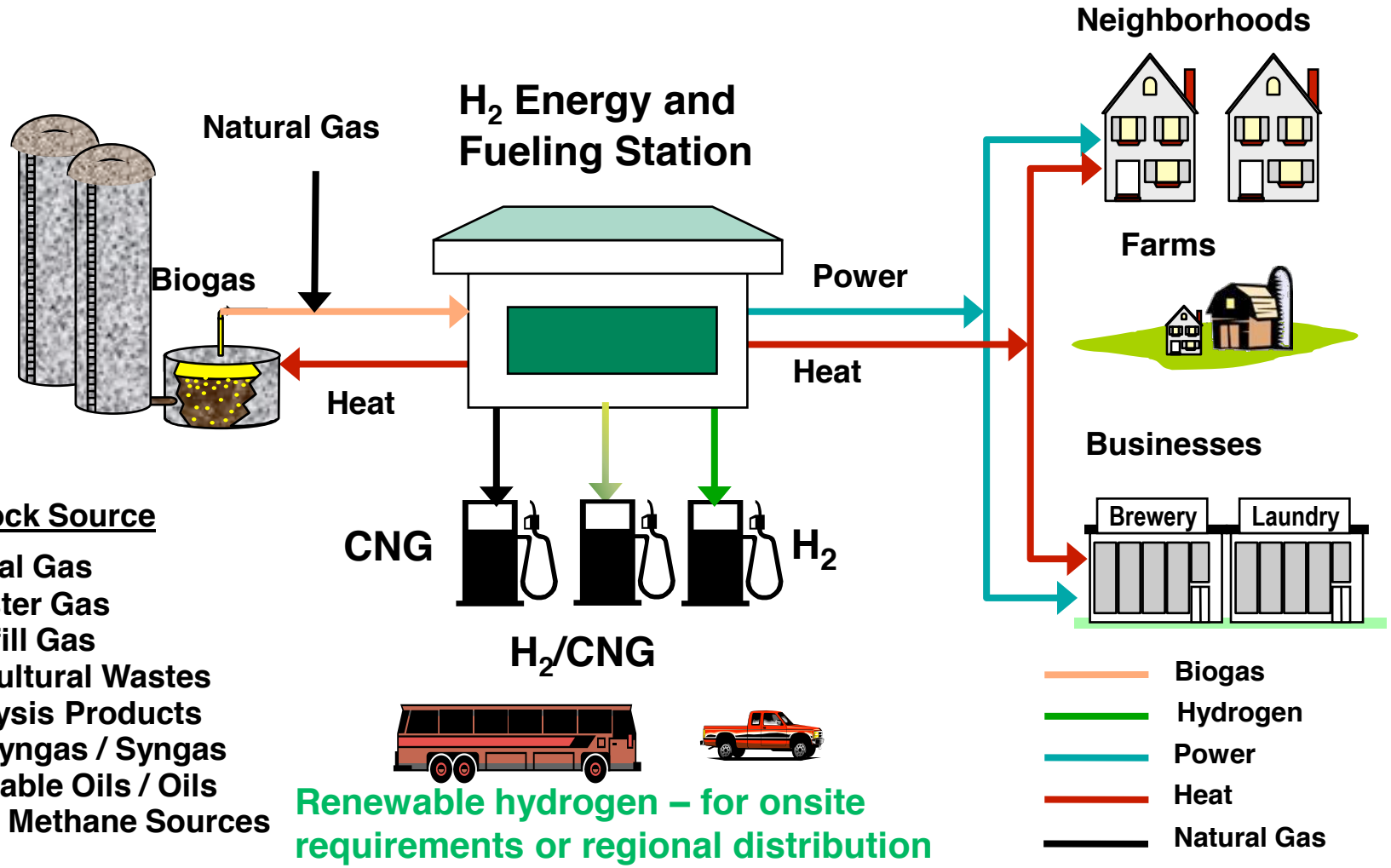


Early Prism® Plants

- Developed in the 1980s
- US energy crisis → heavy subsidies
- Crisis ended → AP sold business
- AP Kept technology rights

- Clean, high BTU gas
- High reliability
- Low maintenance

Hydrogen Energy Station Vision



Feedstock Source

- Natural Gas
- Digester Gas
- Landfill Gas
- Agricultural Wastes
- Pyrolysis Products
- Bio-Syngas / Syngas
- Vegetable Oils / Oils
- Other Methane Sources

Renewable hydrogen – for onsite requirements or regional distribution

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Hydrogen Energy Station Shop Validation Test – DFC® System

All DFC®-H_2-PSA Equipment Installed and Commissioned

Hydrogen Ready Fuel Cell Module

Mechanical Balance of Plant (MBOP)

- DFC® Integrated with Anode Exhaust Skid without H2 purification / export
- PSA System Operation and H2 production
- Tested integrated system

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Hydrogen Energy Station Shop Validation Test – H_2 Purification Skid

Anode Exhaust Processing and H_2 Purification System

- Verified operability of hydrogen-ready DFC®300
- Achieved stable operation at various loads for operation with anaerobic digester off gas feed

- Initial potential will come from UK, Germany, India and Korea
- Timescale to commercial plant 24 months

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Municipal Waste Gasification

- Multiple technology options
- Green method of waste destruction which delivers a green syngas – a CO:H2 gas mix
- The key is cleaning of this syngas
- Gas cleaning is a strategic competence of Air Products
- Significant volumes of hydrogen and power can be generated via this route
- Timescale to commercial plant onstream 36 months

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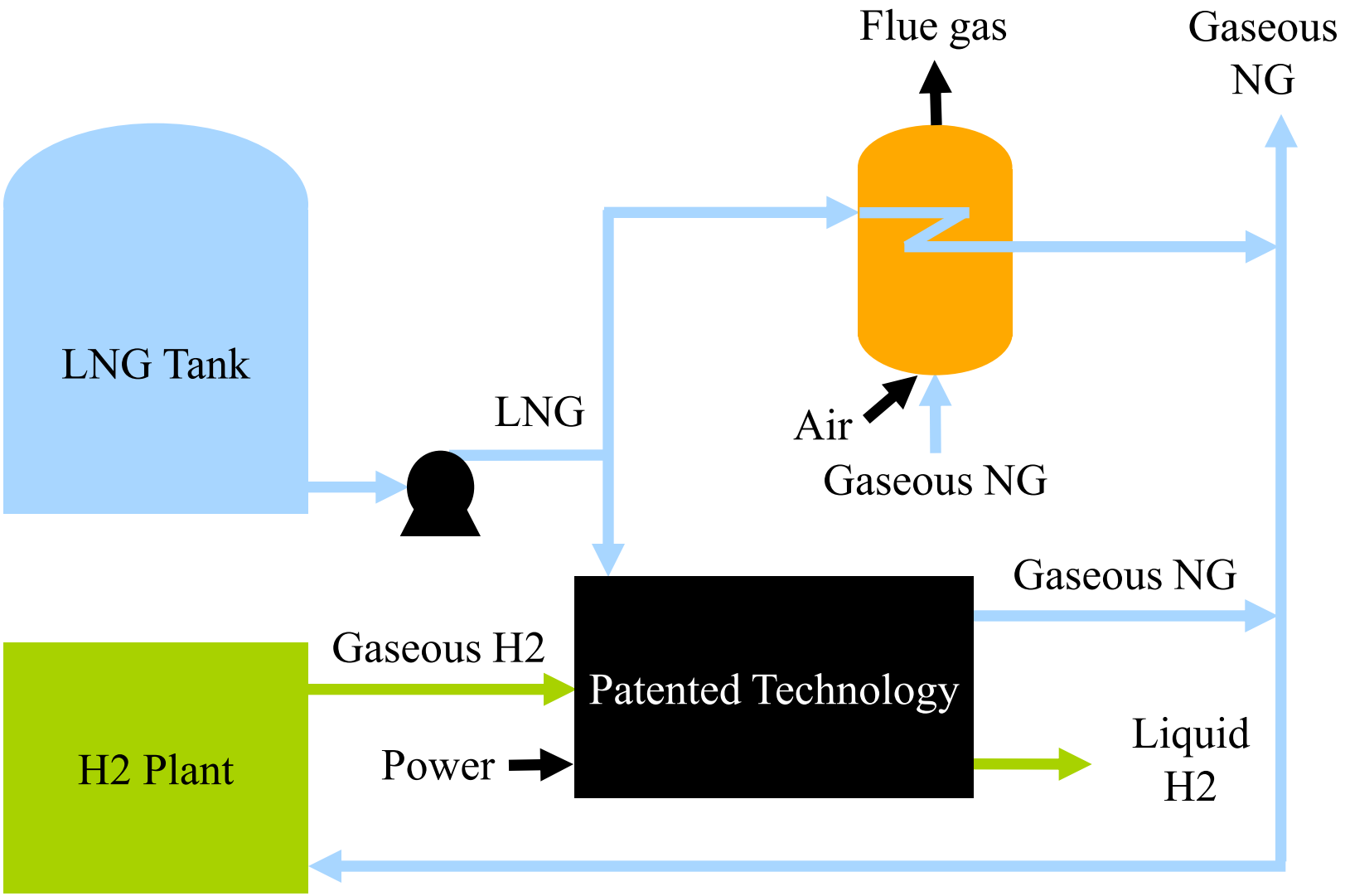
LNG/LHY Integration Technology



The Future…

- Cryogenic gas production has already been integrated with LNG production in France and Japan
- Air Products sees such integration as a primary route to achieve low cost liquefied hydrogen
- The technology for hydrogen has not been done before but the principles will be the same
- There are two main issues:
  - Size of plant to build
    - Pilot plants start at c. 30MT/D
      - existing world scale LHY plant
    - Full scale c. 300MT/D
  - Suppliers/vendors capable of providing the necessary components
- We anticipate such plants will also be built in association with CCS enabled power plants
- Timescale to commercial plant – market dependant

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Central Grocers, Inc.

- Opened March 2009
- 946,000 sft. Warehouse greenfield site
- 140+ MHE fleet, largest under one roof. Expanding to 240 MHE units.
- 3 indoor dispensers, 2 more in a year

HydroJen

Are we truly running on empty?

Like your favorite TV show, fossil fuels won't last forever. But you can't just switch to a new fuel overnight. That's why Air Products, in conjunction with the Da Vinci Science Center and other contributors, developed the hydrogen fuel bus program. We want to get out in the community and educate people about the benefits of using hydrogen fuel.

Where can we still find oil?*

What about gas stations? Where will I get coffee?

Don't worry – hydrogen stations will be just like gas stations. Safe, convenient and easy to use. And we should know: Air Products has installed more than 85 stations in 15 countries around in the world. They don't have coffee yet, but we're working on that.

*(Author, Paul Mann, M.K. Horn, I. Cross, et al. This image is in the public domain, by instructions of the authors.)

HydroJen™ fast facts

- Hydrogen makes up 90% of the known universe, and it is the third most abundant element on Earth.
- Hydrogen is colorless, odorless and nontoxic. It does not produce acid rain, deplete the ozone or produce harmful emissions.
- Hydrogen has the highest combustion energy per pound relative to any other fuel, meaning it is more efficient based on weight.
- Most hydrogen is currently produced out of natural gas or it can be produced from water.
- Today, hydrogen is being used to fuel buses, cars, scooters and forklifts. Hydrogen is also used as a fuel for the NASA space shuttle.
- Air Products is the leading producer of hydrogen and is involved in fueling station projects around the world.

HydrogenFutureToday.com

Hydrogen.

The fuel of the future– today.

With HydroJen™ your guide to hydrogen energy

Program Contributors:

AIR PRODUCTS · SCIENCE CENTER · Ford · LANTA · LehighValley HOSPITAL

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The most abundant fuel in the world.

Really?

Yes, hydrogen is everywhere.

It's in the air we breathe, the water we drink, and now in the cars we drive. And guess what? When you burn it, its main byproduct is water. Much better than that polluting exhaust that currently comes out of most tailpipes. We hate that stuff.

Riding in a hydrogen-powered bus never looked so cool.

There are two of them in the Lehigh Valley and they are truly amazing. They may look like regular buses, but inside is a state-of-the-art Ford hydrogen-powered engine that delivers up to a 99.7 percent reduction in CO_2. Any bus that does that is one we want to get on. See if you can spot them. They're headed to the future.

How can you get involved?

Make sure you ride on the hydrogen bus while at Lehigh Valley Hospital's Cedar Crest Campus. There's also a hydrogen-powered bus operating on the Air Products campus in Allentown, PA. And visit the Da Vinci Science Center to learn more about hydrogen. Discover how and why hydrogen should be developed as a fuel of the future through the center's interactive hydrogen exhibit and programs coming soon. Let's face it – gasoline tells a sad story. It's much more fun to learn about hydrogen.

This brochure can't explain it all.

You may still be curious about hydrogen and all of its benefits and uses as an alternative fuel. Don't worry – we're the experts. We've got it all explained on our website. Just visit HydrogenFutureToday.com, where there is also a fun trivia quiz.

Hydrogen Fueling Station
Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501
800-654-4567

Da Vinci Science Center
3145 Hamilton Boulevard Bypass
Allentown, PA 18103
484-664-1002
Open Monday through Saturday 9:30 a.m. to 5:00 p.m.
Sunday 12:00 noon to 5:00 p.m.

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The Bottom Line

- The use of Hydrogen as a fuel continues to make strides globally in many markets
- Commercial benefits exist today in some geographies which will drive FC cost reduction
- Car company commitment to role out mass produced vehicles by 2015
- Air Products has become a recognised leader in hydrogen fueling in the world
- Hydrogen is the ***only*** fuel that over the long run, has the ability to meet objectives regarding energy independence, greenhouse gas emissions ***and*** sustainability
- Methods of large scale green hydrogen production are just around the corner

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Thank you

tell me more

www.airproducts.com/H2energy