

# ANG Technology

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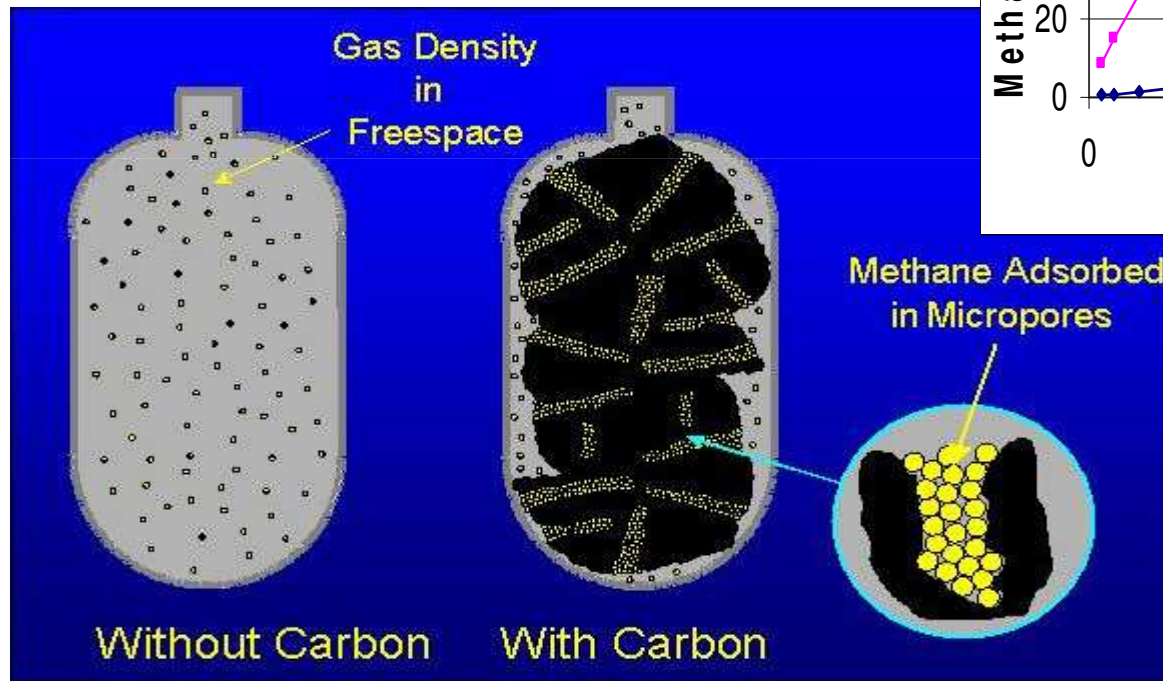
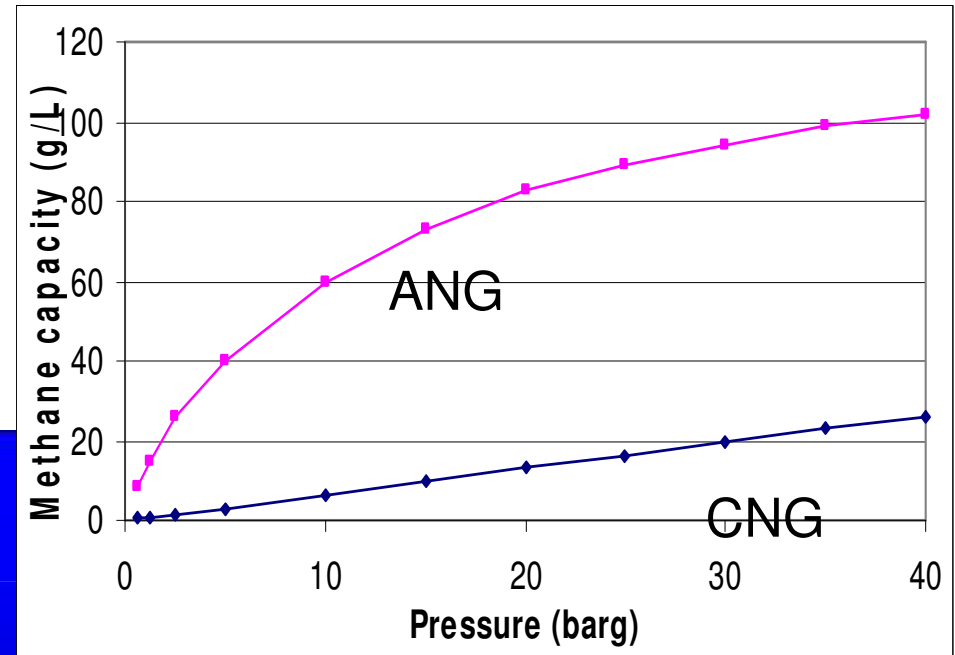
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# Introduction

- What is ANG?
- What are the benefits?
- What are the risks and challenges?
- Applications:
  - Road vehicles
  - Bulk scale natural gas storage and transport
- Where are we on the road map to development?

# ANG technology

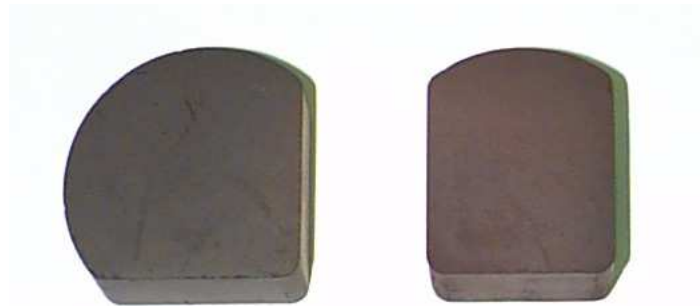
- Adsorption of natural gas onto activated carbon at low pressures, up to about 35bar
- Carbons specially designed to achieve maximum capacity
- Greater energy density than CNG at same pressure up to 100bar. Several times capacity of CNG at about 35 bar pressure



ANG

# Carbons

- Produced from a wide range of naturally occurring materials
  - Eg coconuts, wood fibre, peach pits, coal
  - Different raw materials lead to different properties
- Activation at high temperature opens up micropores.
- Chemical treatment can increase micropore volume.
- Final form – granules, pellets, extrudates, monoliths



# ANG comparison

Energy Density (rel to natural gas at 1 bar)	200	100	600
Pressure, bar	200	35	8
Space usage	30-50%	Up to 95%	Up to 90%
Safety (relative to CNG)		Better	Worse (wider flammability range + pooling)
Emissions relative to CNG		Same	Worse (x2)
Est. Fuelling Capex (rel to CNG)		About 60%	Infrastructure dependent
Est. Fuelling Opex (rel to CNG)		About 60%	

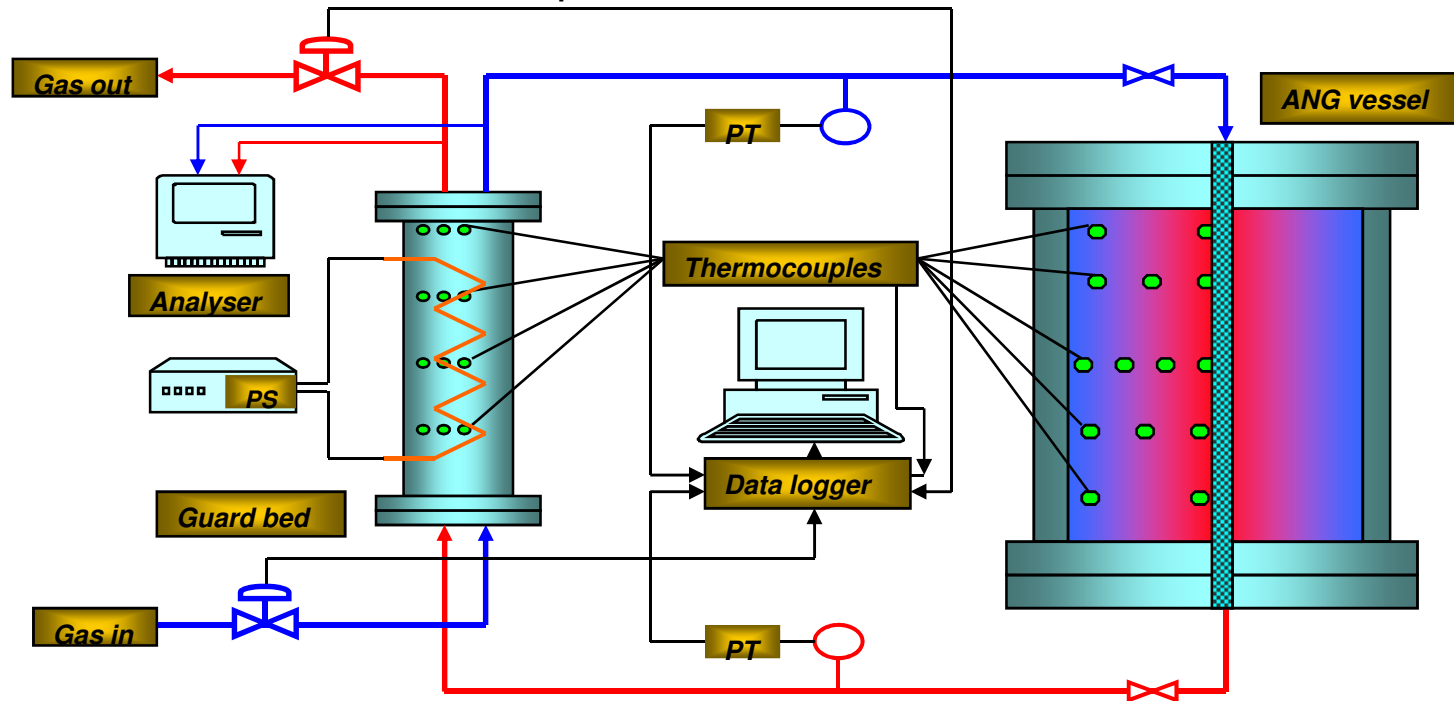
# ANG – Adsorbed Natural gas

- Early work focused on development for vehicles
  - Emphasis on high performance carbon development
  - Carbons store up to 150v/v (volumes of gas per volume of space) at 35bar
- Bulk scale and ‘Diurnal Storage’ have different set of technical and economic issues to vehicles
  - Lower storage capacity materials at significantly lower cost can still provide big benefits
- Technology needs to be understood and optimised for each individual application

# ANG development at Advantica /GL

Fully integrated test facility  
Computer modelling  
System design studies

Safety studies  
Extensive technology development  
Several sole and collaborative programmes  
Multi-component Dynamic models of storage processes



# Targets

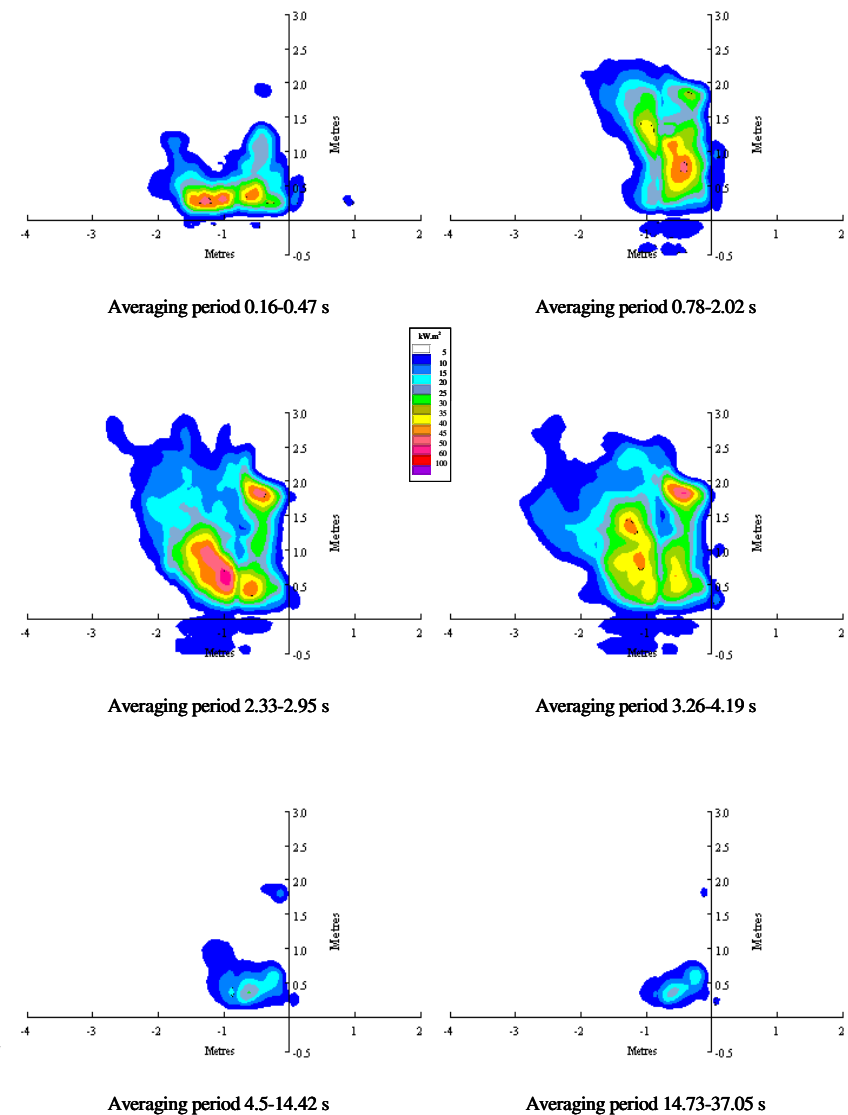
- High adsorption capacity carbons/minimum cost
- Maximum enhancement factor (ANG/CNG capacity ratio)
- Minimum CAPEX/Capacity ratio (minimum system complexity)

# Challenges

- Adsorption releases heat - needs to be managed
  - heat reduces capacity
- Carbons are microporous - need to be protected from large molecules
  - pentane + and odorants
  - If not capacity will slowly diminish, but can be reversed
  - Guard bed
- Much of gas is stored at relatively low pressures – need to discharge to as low a pressure as possible.
  - Deliverability is not same as capacity
  - Need to configure so that there is minimum resistance to diffusion

# Safety

- Experimental tests at Spadeadam with quantified outputs
- Model developed to incorporate mechanics relating to ANG particles
- Outputs used to develop safety cases and hazard contours
- In general, many hazards associated with ANG appear to be **reduced** in comparison with CNG cases at similar pressure.
  - Peak gas dispersion and jet distances are reduced.
  - The cooling effect of the desorption process limits peak flow rates.
  - For an equivalent storage capacity, ANG pressure will be lower, giving a further safety gain.



# Guard bed: gas quality impact

- Guard Bed purpose:
  - Pre-adsorption vessel (2% of size)
  - Removal of higher hydrocarbons and odorants from natural gas to avoid long term damage of main vessel carbon
  - Recovery of odorants during emptying phase of cycle
  - Temperature vs. pressure regeneration
- Key issues:
  - Choice of suitable carbon
  - Direct vs. indirect heating method
  - Need to maintain odorant levels within specifications
  - Minimum pressure drop

# ANG technology for vehicles

- Storage systems have been designed in conformable, flat, non-cylindrical shapes
- Tested on vehicles to over 25,000 miles with no deterioration in performance



# ANG for 2-wheelers

Natural Gas



Liquefied Petroleum Gas (LPG)

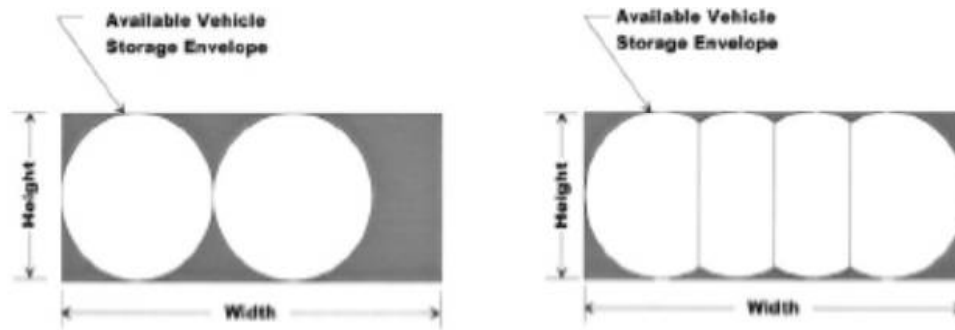


- Electricity (battery)
- Hydrogen (Methanol/Ethanol)



# Vehicle benefits

- Reduced operating pressure leading to improved safety
- Potentially easier to gain regulatory approvals
- Reduced need for costly compression at refuelling station
- Space efficient conformable tank
  - Space, aesthetics can lead to improved driveability
  - Tank can be designed to fit available space in vehicle

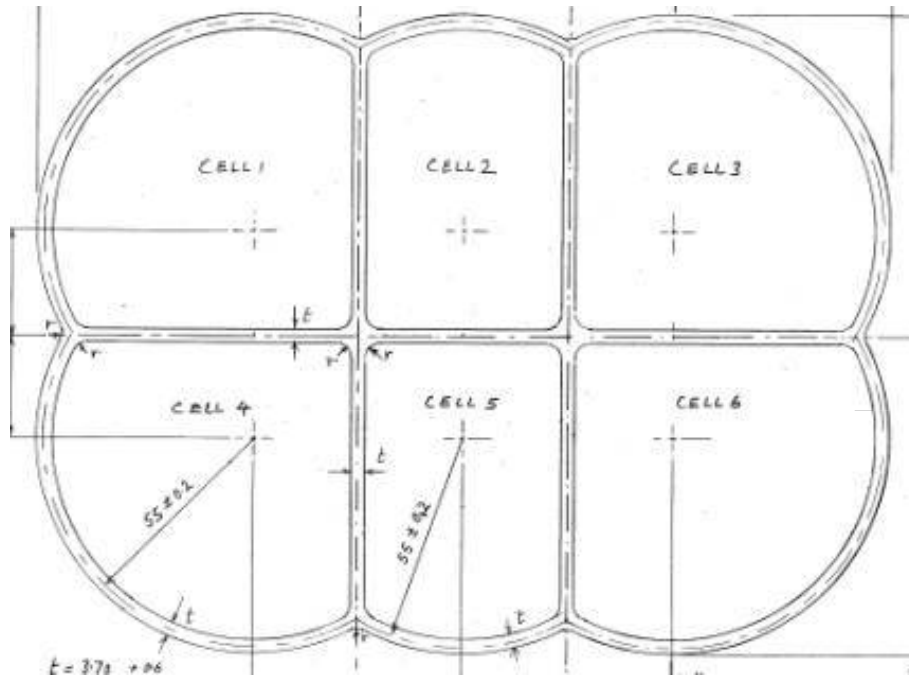


- **Higher volumetric capacity through conformability.**
  - Eg For a scooter, a 8L tank gives a range of over 60km, compared to 30km by 2L CNG tank
- **Potential for removable tanks –**  
Offline filling and distribution can increase spread of market

# Vehicles: technical challenges

- Integration of tanks and conversion Kit
  - using space on vehicle for retrofit without disturbing vehicle design, handling or conflicting with regulations
  - unique tank design to suit retrofitting of all vehicles
  - Ultimately aim for OEM integration
- Fuelling and Delivery
  - design of fast fuelling systems to conform to regulations
  - development of dedicated fuelling nozzles for ANG
  - maximising range from tank
- Gas quality, lifetime and maintenance
  - effect of gas quality on carbon adsorption efficiency

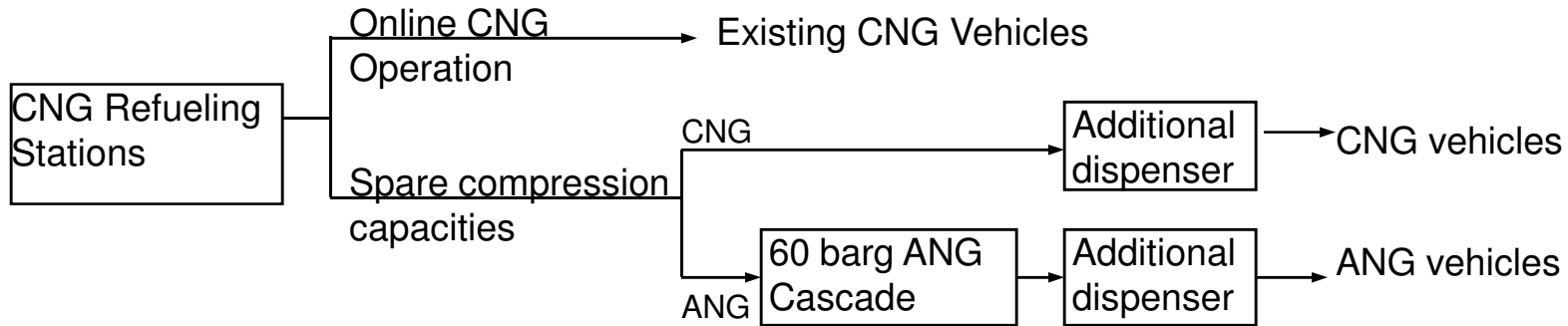
# Tank design and manufacturing



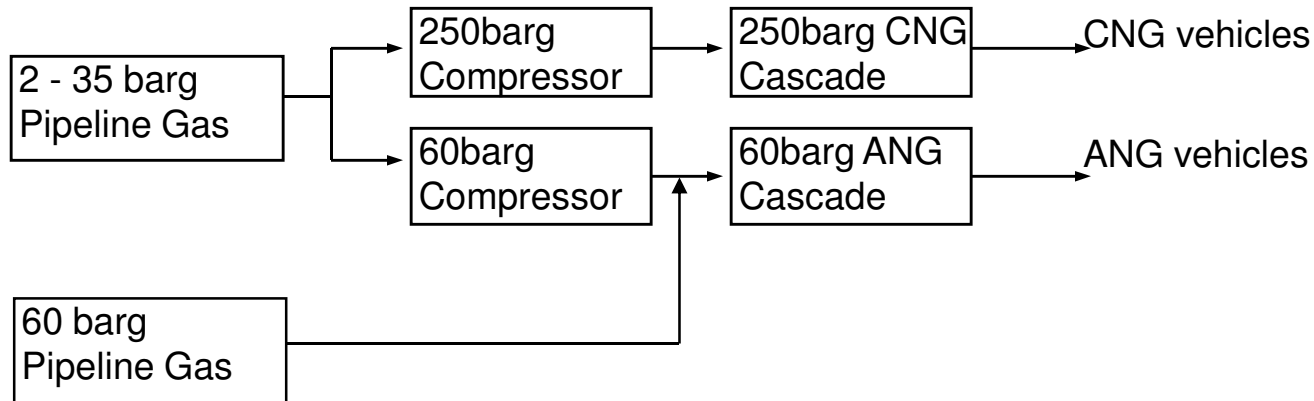
- Example of possibilities with Advantica/GL developed AGLARG tank
- Volume 8 litres
- Based on Extruded aluminium
- Filled with carbon and end caps welded
- Weight about 6kg
- ***Dimensions can easily be modified.***

# Refuelling facilities- possible examples

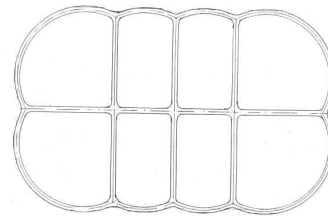
## Initial Stage: Expansion at Existing Stations (First 20,000 vehicles)



## Second Stage: Investment in New Stations



# Scooter conversion



Height = Variable  
Weight = 6-7kg (incl C)  
Range = 40~50km (7-8L)  
Tank cost = £40

- Fits multiple vehicles by changing length

# Work Programme

To prove the concept of ANG:

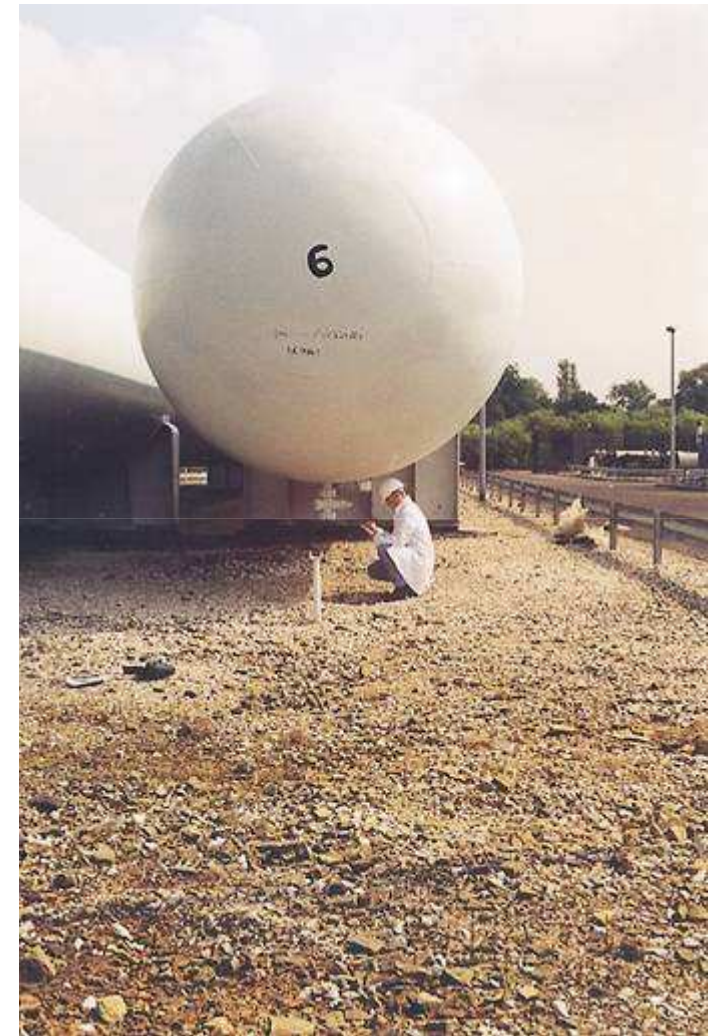
- Quick filling time (< 1 min) –
- Gas storage and delivery (minimum 90 v/v @ 50 barg) –
- Successful conversion and an operational ANG scooter



# ANG Diurnal Storage

ANG offers:

- Increased capacity per volume
- Up to 4 x increase in capacity
- Lower storage costs per unit of gas
- Safety advantages



## ANG diurnal storage - benefits

Storage distributed close to point of use, removing dependence on Transmission system

Flexibility of siting

Lower safety hazards than CNG

Lower visual impact and footprint (40-50 volumetric enhancement over LP gas holders at 20-25bar storage pressure)

Low OPEX –10 times less than holders

Below ground installation possible

Modular nature allows construction of banks of vessels

Just-in-time approach to construction –CAPEX phasing

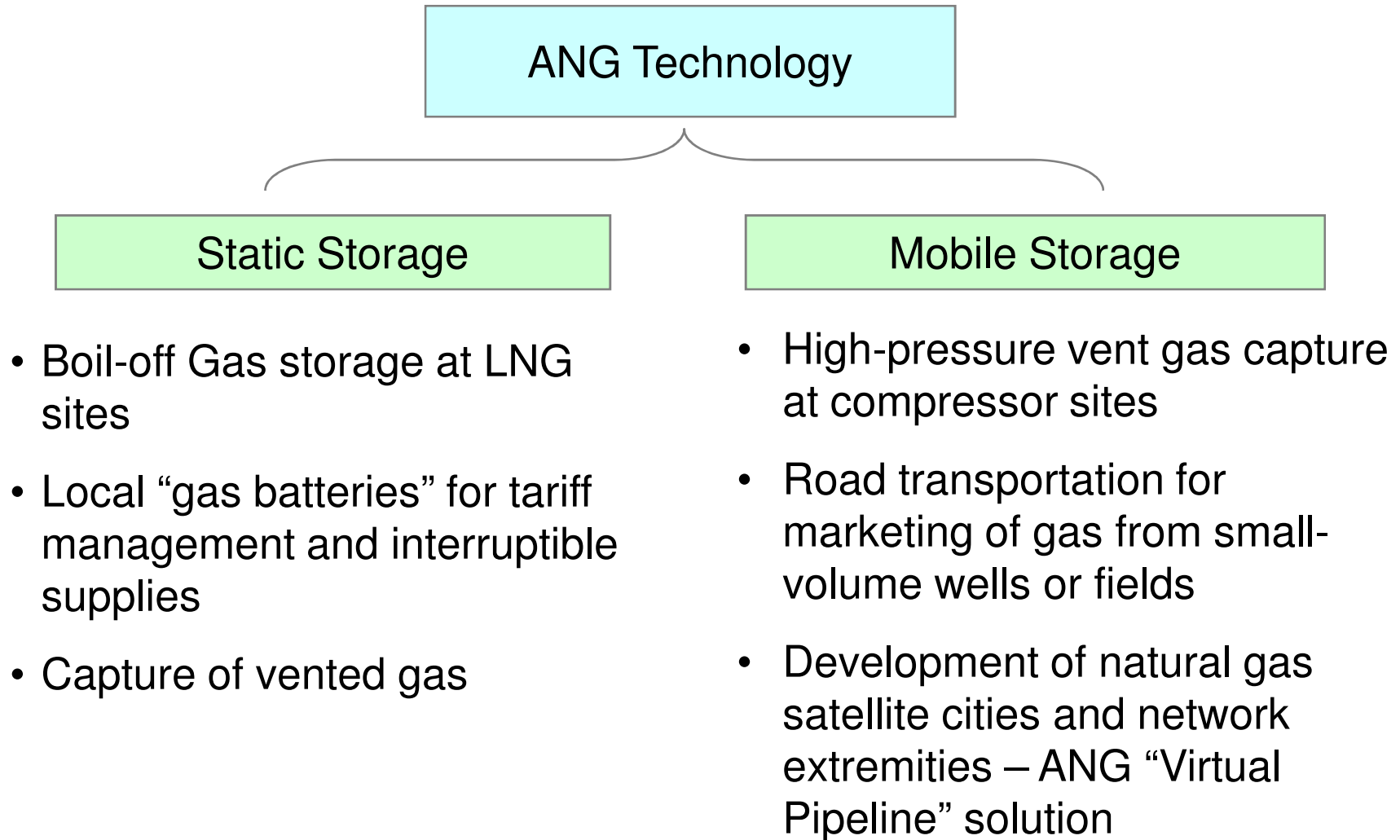
# Diurnal and bulk storage

- Different set of issues from vehicles
- Economics depend critically on cost of carbon
- Cost of carbon increases disproportionately with performance
- Density of carbon is issue – carbons priced by weight so lower density leads to lower cost per volume
- Economics show complex interplay between carbon performance and cost
- Standard granular carbons have significant benefits

# Bulk storage - status

- Carbons (adsorbent) screening and characterisation
- Models developed for multi-component dynamic operation
- Heat management options developed
- Simulation of field trial conditions for integrated system
- Multi-cycling operation demonstrated at small pilot scale
- Safety contours identified through experiment and modelling
- Gas quality issues addressed
- Field trial designs produced and costed

# Other Potential ANG Applications



# Advantages

## Operation

- Storage distributed close to point of use, removing dependence on transmission system
- Maintain pipeline pressure at network extremities

## Planning and Economics

- Modular nature allows construction of a bank of vessels according to demand expansion
- Just-in-time approach to construction –CAPEX phasing (unlike linepack)
- Low OPEX – 10 times less than LP gas holders
- No extensive inlet compression (like CNG) is required

## Safety

- Lower safety hazards than CNG (7-40 barg vs 200 barg)
- Lower footprint and visual impact (40-50 volumetric enhancement over LP gas holders at 25 barg storage pressure)

# Conclusions

- ANG has strong potential for a number of natural gas markets
- Both cars and 2 wheelers have been successfully demonstrated. CNG infrastructure needs modification to develop market.
- ANG for diurnal storage can provide significant economic and operational benefits over alternatives.
- ANG can be a potentially safe and economical alternative to CNG or other storage and transport options, and can greatly reduce environmental impact of operations.