



# **Commercialising Hydrogen Storage Technology**

IPHE Meeting  
Gold Coast, Australia  
20 June 2008

# Agenda

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- Who is Hydrexia?
- Hydrexia's technology
- The hydrogen storage market
- Hydrexia's target applications and value proposition
- Hydrexia's commercialisation strategy
- Challenges for the commercialisation of the new hydrogen market
- Summary

**Who is Hydrexia?**

# Who is Hydrexia?

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- Hydrogen storage systems company based in Brisbane, Australia
- Commercialising technology based on proprietary magnesium alloys
- Spun-out from The University of Queensland, Brisbane, Australia in June 2006
- Closed a AUD4.8 million, Series A funding round in November 2007 with Australian and international VC investors
- Signed a Cooperative Agreement with a global industrial gas company in May 2008

# History

	MILESTONES	SAMPLE SIZE TESTED	EXTERNAL FUNDS RAISED
2002	<ul style="list-style-type: none"> <li>• Research @ UQ commenced</li> </ul>		
2004	<ul style="list-style-type: none"> <li>• 'Trailblazer' award</li> <li>• Hydrexia company registration</li> </ul>	1-2g	\$40,000
2005	<ul style="list-style-type: none"> <li>• ISUS grant</li> <li>• QSEIF grant</li> <li>• Business Plan formalised</li> <li>• Enterprize competition</li> <li>• PCT application</li> <li>• JN appointed CEO</li> </ul>	1-2g	\$330,000
2006	<ul style="list-style-type: none"> <li>• Business Plan validated</li> <li>• Seed round closed, Jun 06</li> <li>• 1<sup>st</sup> Research Contract with UQ</li> <li>• Lab commissioned</li> <li>• 1<sup>st</sup> prototype built</li> <li>• 3 employees</li> </ul>	150g	\$850,000
2007	<ul style="list-style-type: none"> <li>• Independent testing of alloy</li> <li>• Cooperative Agreement agreed</li> <li>• 2<sup>nd</sup> Research Contract with UQ</li> <li>• 2nd prototype built</li> <li>• 2 new provisional patents filed</li> <li>• Commercial Ready grant</li> <li>• Series A round closed, Nov 07</li> <li>• 5 employees</li> </ul>	4.4kg	\$5,100,000
2008			<b>TOTAL = \$6,320,000</b>

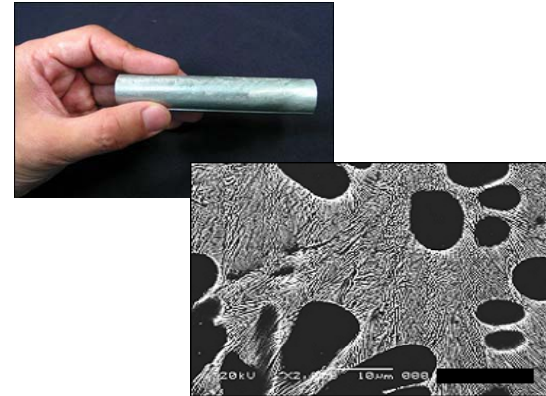
# **Hydrexia's technology**

# Hydrexia's material

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## Material characteristics

- Novel magnesium-nickel alloy composition + small concentrations of refining elements
- Refined, nano-scale structure which catalyses and facilitates H<sub>2</sub> sorption
- Energy of reaction,  $\Delta H = 74.8\text{kJmol}^{-1}$
- Safe to handle in open air in hydrogenated or de-hydrogenated states



## Material production

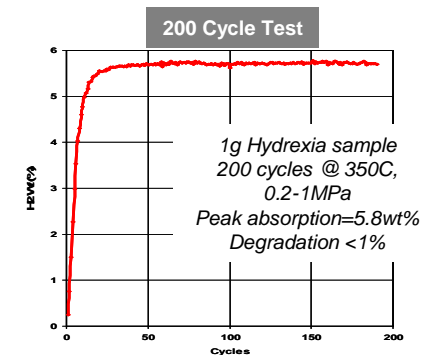
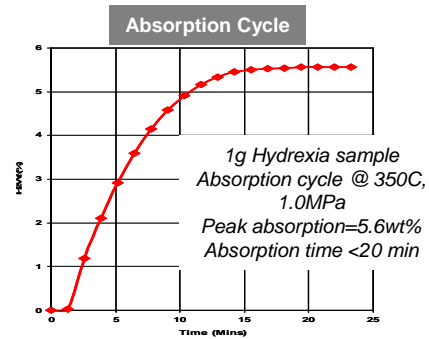
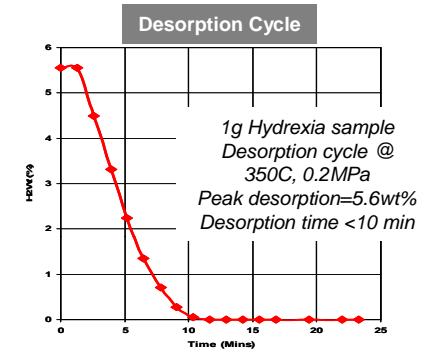
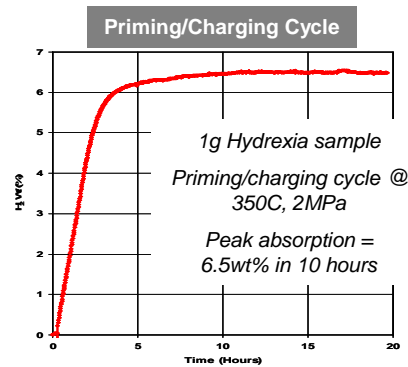
- Manufactured by casting
  - Uses standard foundry equipment and casting techniques
  - Scalable production
  - No ball-milling required
- Used in bulk form
  - Simple, 1 or 2 step on-processing from cast material
- 1<sup>st</sup> 30kg cast completed in April 2008
  - Targeting 1<sup>st</sup> 100kg cast by 31 Dec 08



# Hydrogen sorption performance

## H<sub>2</sub> sorption performance\*

- Storage density - cycled
  - Gravimetric
    - Peak = 7.0wt%<sup>1</sup>
    - Experimental basis = 6.0-6.5wt%<sup>2</sup>
  - Volumetric = up to 32g/l
- Kinetics
  - Absorption: 20-120 minutes
  - Desorption: 10-180 minutes
- Flow rates
  - 0.3-5.0kg per hour per kg H<sub>2</sub> stored
- Material can absorb & desorb from 1st cycle
- Longevity
  - Demonstrated 200 cycle tests with <1% degradation<sup>3</sup>
  - Completed 500 cycle test
  - ~60 days storage in air without drop in performance<sup>4</sup>
- Tested in amounts from 1g through 4.4kg
- **Material performance independently tested & validated by Johnson Matthey plc**



\* As tested in scientific test rigs + prototypes  
 1 1-2g of material @ 350C, 0.1-2MPa  
 2 1-2g of material @ 350C, 0.1-1MPa  
 3 Across 200 cycles  
 4 Activated & hydrogenated material



# Hydrexia's prototype hydrogen storage system development to date

## Prototype P1 & P1.1

- Proof-of-concept system built to demonstrate scale-up
  - Capacity to test up to 500g of material, cycling up to 30g of H<sub>2</sub>
  - Can handle temperatures to 400C and pressures up to 2MPa
  - No active heat loss management but capacity to pull vacuum on outer wall of vessel
- Workhorse to test and develop concepts for future prototypes

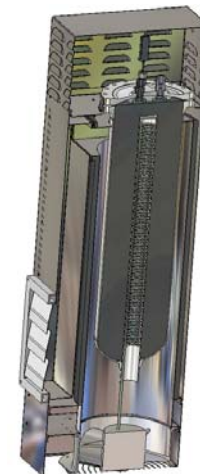


## Finite Element Analysis (FEA) model

- A sophisticated model has been created simulating Hydrexia's material properties within a storage system
- Accurate FEA modelling greatly assists understanding of system dynamics and will accelerate development of future prototypes

## Prototype P2/α1

- Designed as a buffer store
  - 2 pressure vessels, each with capacity of up to 5kg of material/300g of H<sub>2</sub> stored (i.e. total of 10kg of material/600g H<sub>2</sub> stored)
  - Vessels can absorb & desorb independently or in series
- Simple and low cost electrical heating with fan-forced cooling
- Scalable design

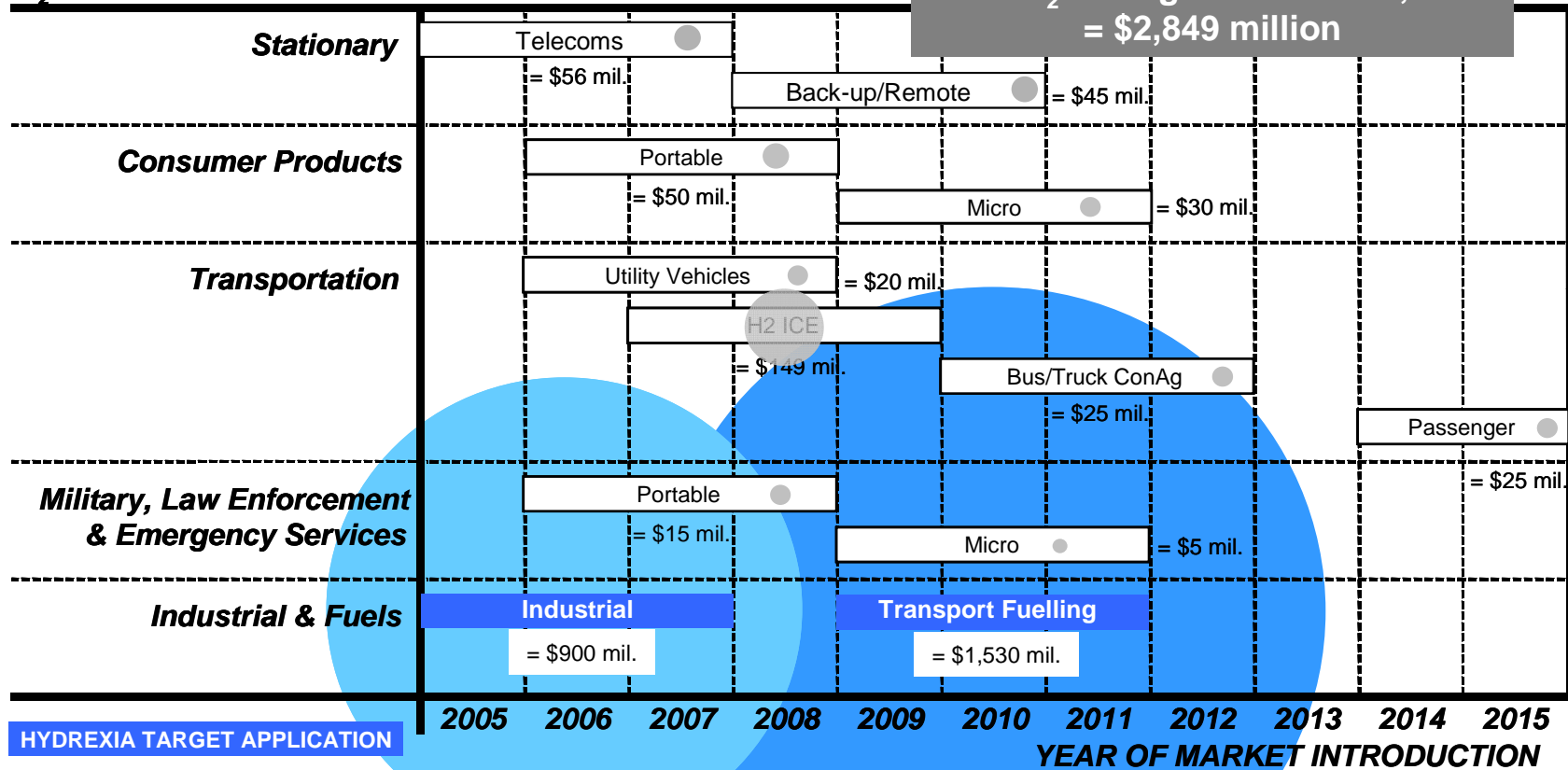


# **The hydrogen storage market**

# Industrial and transport fuelling storage will dominate the market

## H<sub>2</sub> & FUEL CELL APPLICATIONS

Total H<sub>2</sub> Storage Market Size, 2015  
= \$2,849 million



Sources: BCC, Luigi Bonadio Associates market research, Hydrexia market research & estimates

● = \$150 million of sales in 2015

# **Hydrexia's target applications and value proposition**

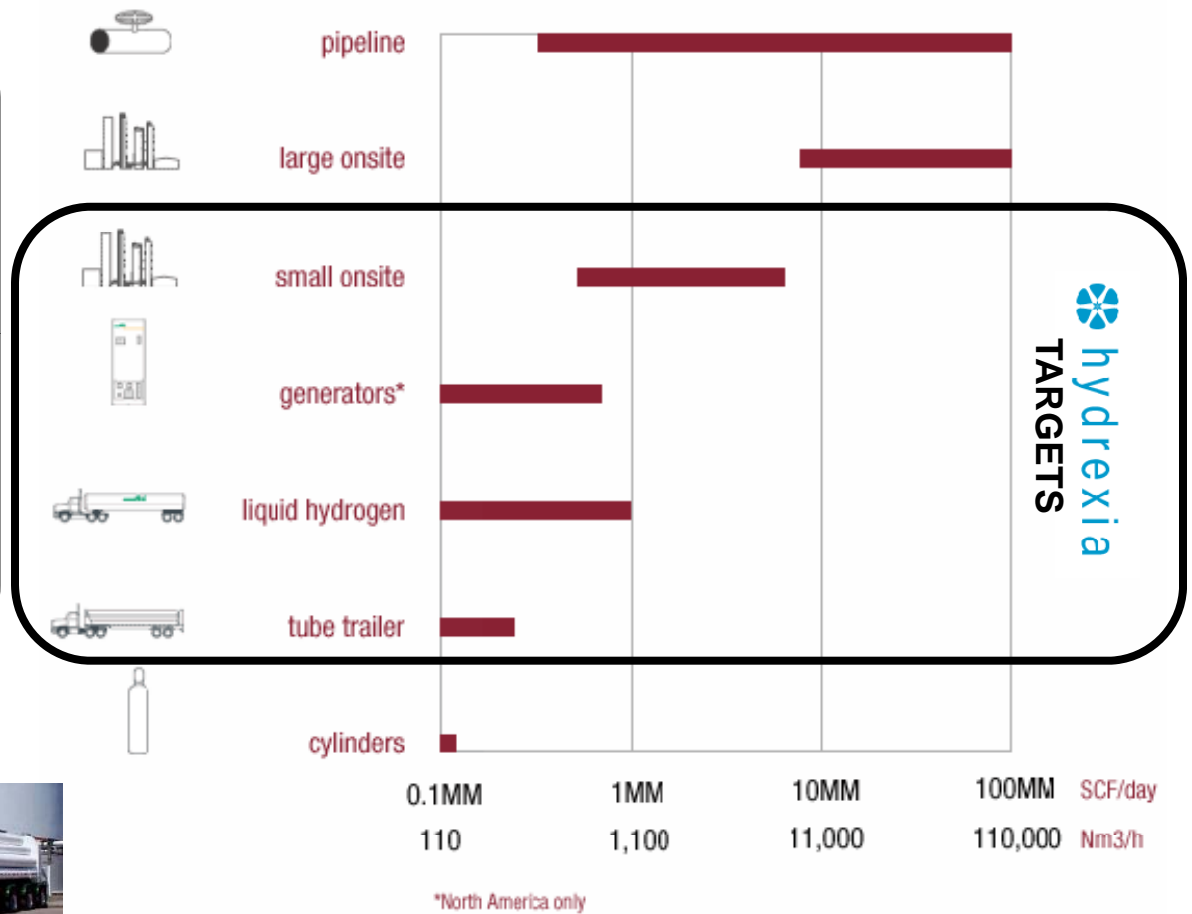
# Industrial H<sub>2</sub> storage is the 1<sup>st</sup> application for development

## INDUSTRIAL APPLICATIONS USING H<sub>2</sub>

- Petroleum recovery & refining
- Chemical processing
- Metal production & fabrication
- Pharmaceuticals
- Aerospace
- Electronics
- Food











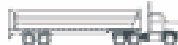

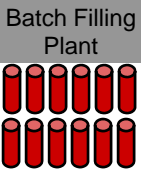




## Industrial H<sub>2</sub> Delivery & Storage Options



Sources: Air Products, Praxair

# Existing vs. potential storage & delivery models

	STORAGE & DELIVERY CONFIGURATION	AVE CUSTOMER USE PER WEEK	FORM OF FILLING	DELIVERY METHOD	USER FORM	PRICE/COST \$/KG H <sub>2</sub>
EXISTING	G/T/K Cylinders	<10 cylinders < 6kg		'One-to-Many'  Max load -cylinders? -H <sub>2</sub> ?		Delivered price = \$495 <sup>1</sup>
	9/15/18 'G' cylinder pallet	2x 15 cylinder pallet? <18kg?		'One-to-Few'  Max load -pallets? -H <sub>2</sub> ?		Delivered price = \$508 <sup>2</sup>
	Tube Trailer	0.15-0.25x tube trailer 40-60kg		'One-to-One'  Max load=200-400kg		?
POTENTIAL	Tube Trailer + Hydrexia Buffer Store	10-25kg		'One-to-Few' 		?
	Batch Plant & Delivery	30-60kg		'One-to-Many'  Max load <sup>3</sup> =200kg H <sub>2</sub>		?

<sup>1</sup> Quoted price for G cylinder. <sup>2</sup> Quoted price for 15-cylinder pallet. Both prices include cost of hydrogen but no leasing costs and no discounts, May 2008; <sup>3</sup> for standard 5 MT Hino truck

Sources: US DOE, BOC, Hydrexia estimates, Hino Australia

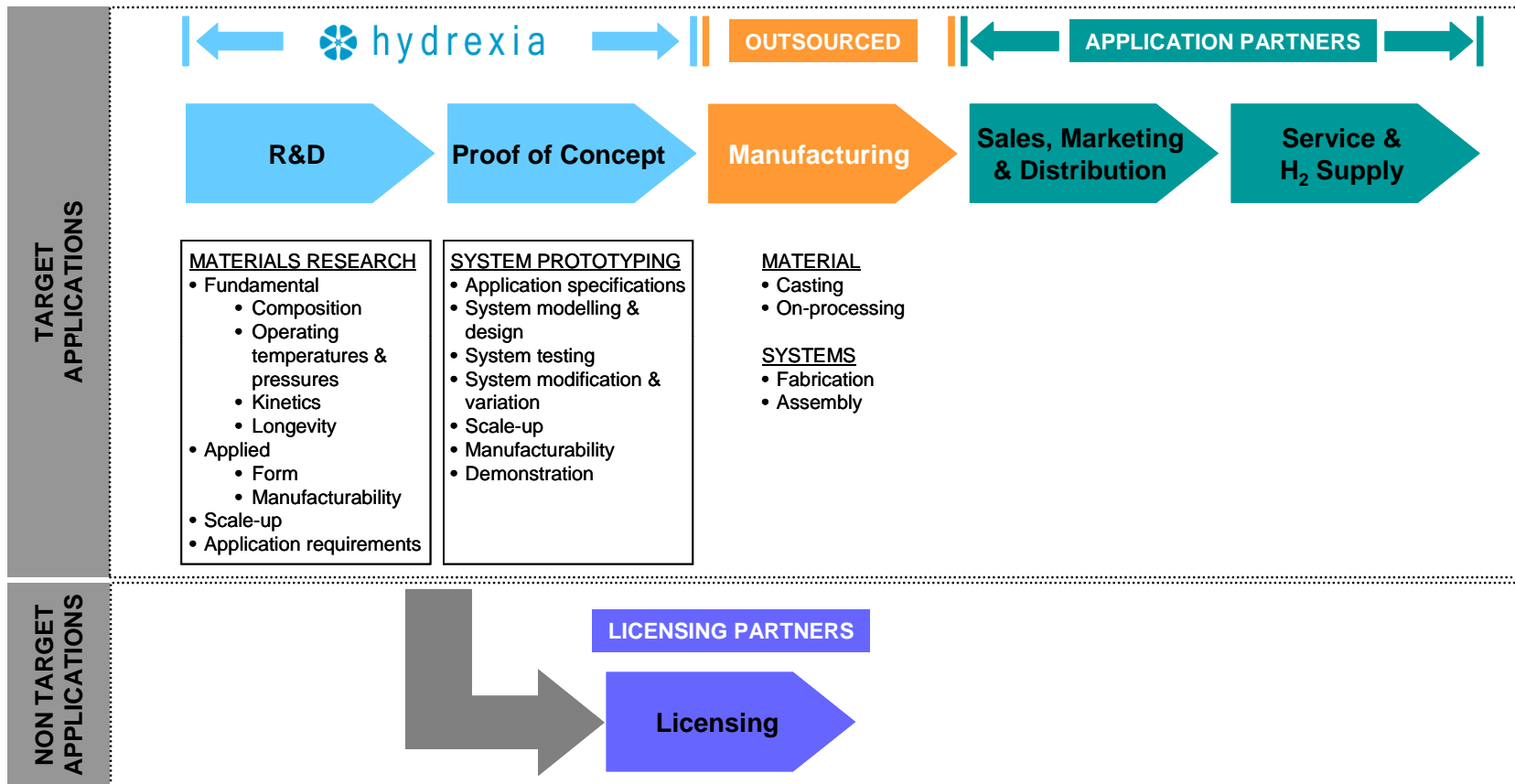
# **Hydrexia demonstrates value-add in 6 key criteria for industrial H<sub>2</sub> storage**

1. Good H<sub>2</sub> sorption performance
2. Lower cost per kg H<sub>2</sub> stored & delivered
3. Improved safety
4. Ability to provide storage solutions that fit with customer requirements
5. Material and systems able to be scaled-up & manufactured easily
6. Solutions can be easily integrated with existing infrastructure

## **Hydrexia's commercialisation strategy**







# Hydrexia's business model



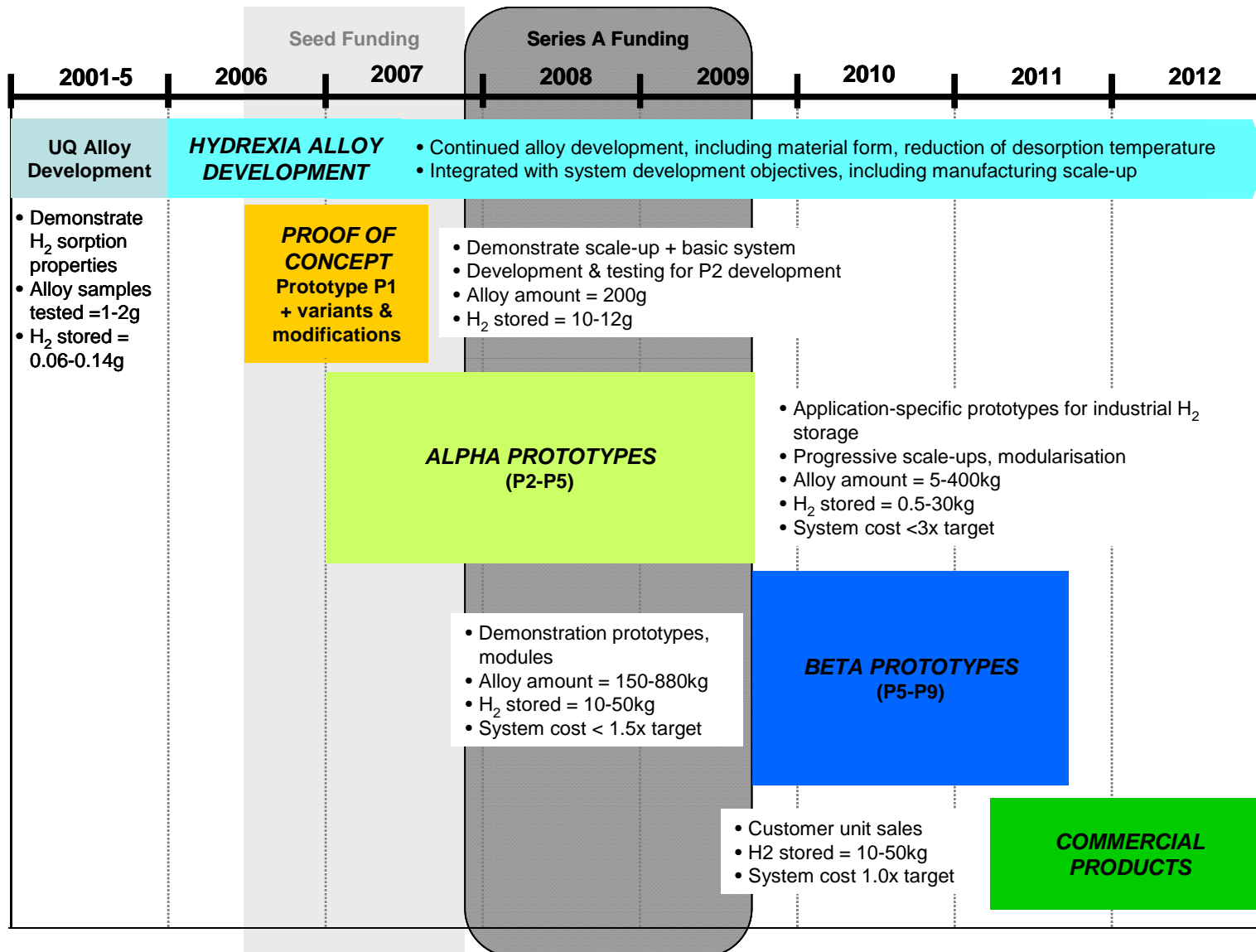
- Hydrexia's business model for target applications is focussed on maximising value from R&D through to Proof of Concept
- Licensing is an option for those applications where Hydrexia is not pursuing active development

# Hydrexia's preferred route-to-market is via partnering

Target Application	Potential Commercialisation Partners
Industrial H <sub>2</sub> Storage	<p><b>INDUSTRIAL GASES</b></p>  <p>THE LINDE GROUP   AIR LIQUIDE   AIR PRODUCTS   PRAXAIR   TAIYO NIPPON SANSO The Gas Professionals</p>
Transport Fuelling Infrastructure	<p><b>INDUSTRIAL GASES</b></p>  <p>THE LINDE GROUP   AIR LIQUIDE   AIR PRODUCTS   PRAXAIR   TAIYO NIPPON SANSO The Gas Professionals</p> <p><b>FUELS</b></p>  <p>Chevron   Shell   bp   TOTAL</p> <p><b>LIFT TRUCK FC SYSTEM INTEGRATORS</b></p>  <p>plug power</p>

- Hydrexia is seeking to provide a path-to-market by partnering with leading players in each target application
- Hydrexia signed a Cooperative Agreement with a global industrial gas company in May 2008

# System development to commercial product will take 3-4 years



# **Challenges for the commercialisation of the new hydrogen market**

# Is the new H<sub>2</sub> market reaching or at a tipping point?

## MARKET

- Growth in existing market largely 'in-the-fence'
- New H<sub>2</sub> market needs product... but timelines keep slipping
  - Storage the last major technical hurdle
- Some way to go before reaching any critical mass
  - Not even at multi-niche stage
- Automotive shapes too much public perception?

## POLICY

- Inconsistency within & between all levels of government
- Commitment is too binary
- Focus of programs either too narrow or too broad, when probably need a mix of both
- Governments & policy need to actively shape this market
  - Policy provides the direction
  - Purchasing builds the market

## REGS, CODES & STANDARDS

- Shift from industrial to consumer-focus is HUGE in both mindset and application
- Difficult for new products and applications when there is little/no experience
  - Is this holding-up/impeding commercialisation?
- Harmonisation happening too slowly and inconsistently?

## INVESTMENT

### Capital markets:

- H<sub>2</sub> being viewed as less attractive?
  - Too long term as market not developing fast enough
  - Competing 'share-of-mind' with other energy/cleantech alternatives
  - Too many false dawns?

### Public funding:

- Commitment is too binary
- Grant programs either too narrow or too broad when both are needed

# Summary

# Summary

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- Hydrexia has a low cost Mg-Ni alloy that:
  - Demonstrates good H<sub>2</sub> sorption performance
  - Is low cost
  - Can easily be scaled up and manufactured
  - Is robust and easily handled
  - Has been tested to scale, and
  - Has been independently tested & validated
- Large-scale, off-board H<sub>2</sub> storage in the existing industrial H<sub>2</sub> storage market and emerging fuelling infrastructure markets will dominate the storage market in the near to medium terms
- The existing industrial hydrogen storage market is Hydrexia's first application to be targeted
  - Hydrexia can deliver increased value across 6 key criteria
  - Provides a pathway to develop product for the emerging fuelling infrastructure market
- Hydrexia will partner with existing players to increase speed and access to market
  - A Cooperative Agreement with a global, industrial gas company was signed in May 2008
- Hydrexia's first commercial product is targeted in 3-4 years
- The next 5 years will significantly shape the development of the new H<sub>2</sub> markets



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