



LG Fuel Cell Systems

Overview Presentation

Hydrogen and Fuel Cell Technical Advisory Committee

April 23-24, 2013

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Agenda

- **Introduction to LG Fuel Cell Systems (LGFCS)**
- **Introduction to LGFCS' Shareholders**
- **LGFCS Product & Technology**
- **Market Rationale and Opportunity**
- **Summary & Acknowledgements**

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LG Fuel Cell Systems Inc.

The Vision...

***“LG Fuel Cell Systems operating
in every city in the world”***

The Mission...

***“To produce a commercially viable, 1MW
distributed power solution, that sets the global
benchmark for efficient clean power.”***

LG Fuel Cell Systems Inc.

Backgrounder

- A group of LG companies (Corp, Electronics, & Chemical) acquired 51% ownership of Rolls-Royce Fuel Cell Systems Inc. (June 2012)
- As part of the acquisition, LG immediately added value with people, capability, and funding in to the business.
- The business focus remains on the commercialization of a “megawatt-scale” natural gas fueled fuel cell power system for stationary power generation
- The business has its primary activities in Canton, Ohio, with continued support from the team in Derby, England, and a new team of resources based in Seoul, Korea.
- The business is leveraging and benefiting from expertise and capabilities from both LG Group and RR Group

LG Fuel Cell Systems Inc.

Backgrounder Cont.

- The business has transitioned from “research and development” to “development and demonstration” → heading toward commercialization
- The shareholders are investing to develop and test an integrated-system demonstrator, then transitioning to a commercial business
- A program of work is being executed to design, develop, and test a prototype system in a “string-test”
- The “string-test” fuel cell power system will...
 - be at a smaller scale than 1MW, but include a product architecture capable of ‘scaling’ to ~1MW
- This phase of the business will be a success based upon...
 - furthering technology development and completing a ‘string-test’ demonstrating fuel-in to power-out; and
 - completing a business case, cost model, and commercialization plan demonstrating a viable business for the shareholders

LG Fuel Cell Systems

Business Locations / Areas of Expertise

Canton, Ohio



- Overall Business Leadership
- Engineering & program leadership
- Fuel cell development & test
- Fuel processor development & test
- System integration & packaging
- Power electronics
- Control software development
- Control hardware specification
- Prototype Manufacturing

Derby, UK



- Generator module design
- Control software development
- System modeling & analysis
- Block testing

Seoul, Korea

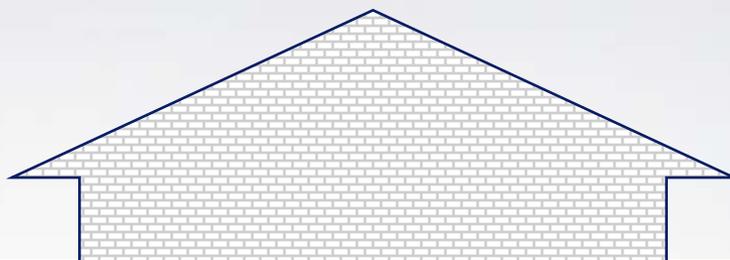


- Supply-chain management
- Fuel cell research
- Manufacturing process development

Foundational Value in to LG Fuel Cell Systems



Fuel Cell Systems Inc.



Rolls-Royce Group

- Turbine & compressor
- Aero-thermal expertise
- High-temp Materials
- Power Electronics
- System Integration



Rolls-Royce Fuel Cells

- FC Technology
- Fuel Processing
- System Engineering
- Design & Modeling
- Scaled Testing
- Years of know-how



LG Group

- Process Development
- Volume Manufacturing
- Design for Manufacturing
- Supply-Chain Development
- Electronics and Controls

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Automobile Solutions



- Battery
- Electric Components
- EV Module

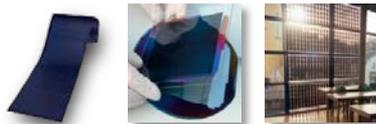
Living Eco Solutions



- Commercial Air Conditioner
- Water Treatment
- Lighting



Energy Solutions



- Solar Cell
- Fuel Cell
- Smart Consumer Solution

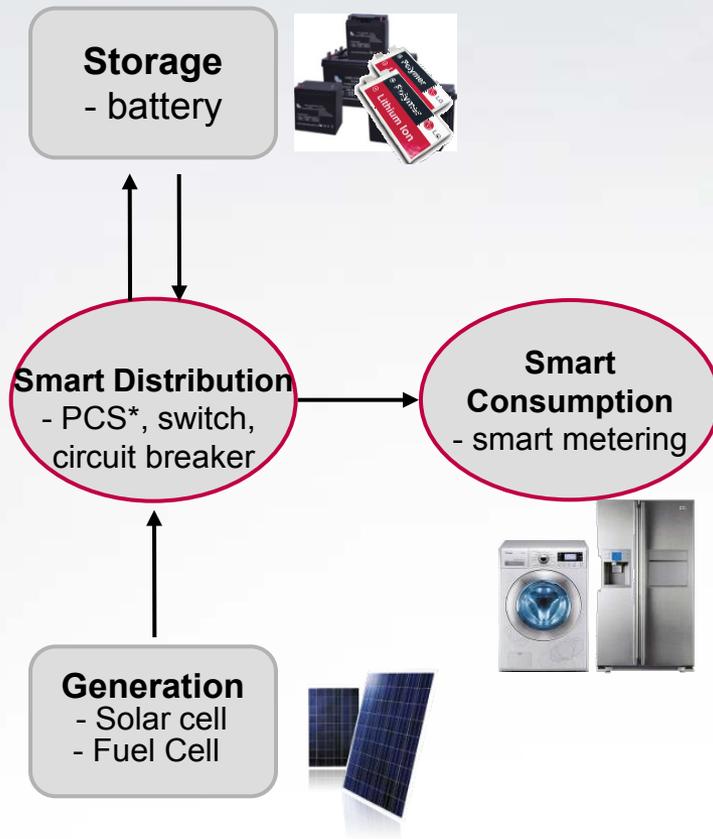
Healthcare Solutions



- Medical & Silvercare Device
- U-Healthcare Solution

Business scope

(Microgrid solution, Smart consumption solution)



* Power Conditioning System

Status and future plan

- **Developing microgrid and smart consumption solution**
 - Megawatt-level lithium-ion battery
 - AC-DC inverter, power transformer
- **Entering smart home business**
 - Server and electronics for smart home
 - Home battery system
- **Ramping up generation capabilities**
 - 330MW scale solar cell factory (Gumi, Korea)
 - SOFC for stationary power



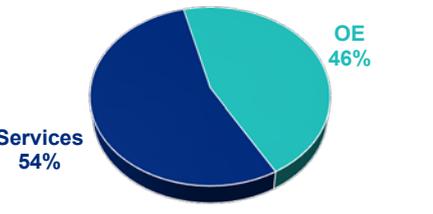
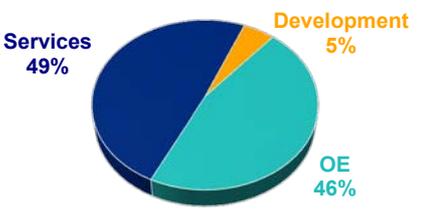
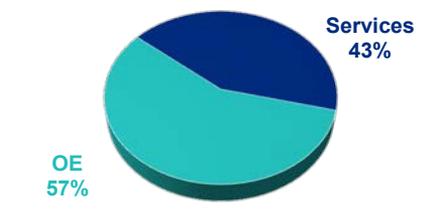
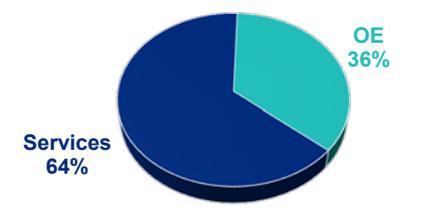
Rolls-Royce Group

Trusted to deliver excellence



Rolls-Royce

Four global markets

Civil Aerospace	Defence Aerospace	Marine	Energy
			
<ul style="list-style-type: none"> • 12,500 engines • Powers 30 types of aircraft • 300 airline & leasing customers • 20 million flying hours in 2012 • 73% of service revenue covered by LTSAs – TotalCare 	<ul style="list-style-type: none"> • 18,000 engines • 24 engine programmes • 103 countries • 160 armed forces • 25% of service revenue covered by LTSAs - MissionCare 	<ul style="list-style-type: none"> • 25,000 propulsion units • 4,000 customers • 70 navies • Products on 30,000 vessels • 5% of service revenue covered by LTSAs – mainly Naval 	<ul style="list-style-type: none"> • 4,000 power systems • 1,600 customers • 120 countries • 25% of service revenue covered by LTSAs
FY 2012 revenue £6,437m	FY 2012 revenue £2,417m	FY 2012 revenue £2,249m	FY 2012 revenue £962m
			
FY 2012 ROS 11.3%	FY 2012 ROS 16.7%	FY 2012 ROS 13.1%	FY 2012 ROS 2.2%

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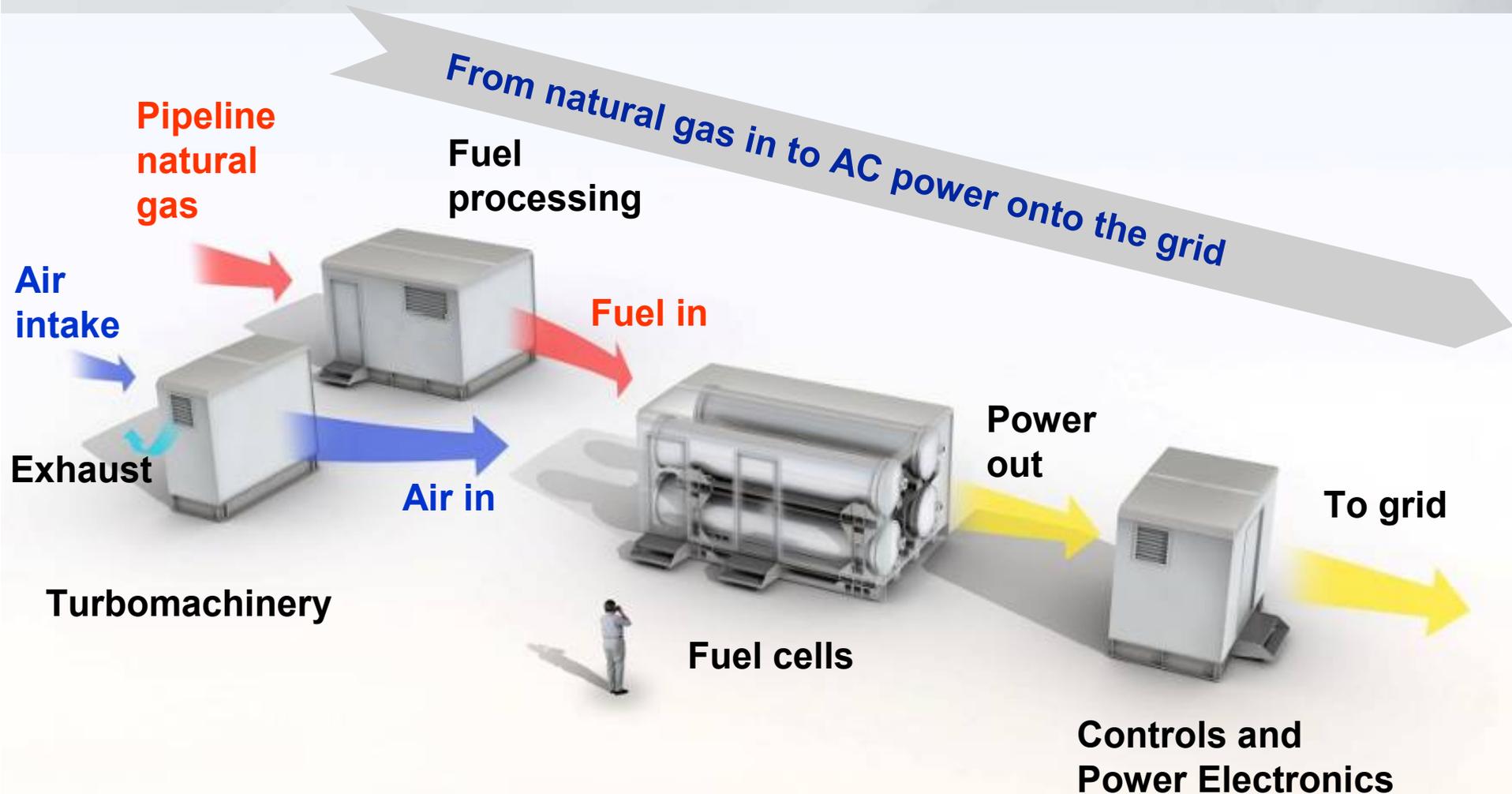
The Product – 1 MW SOFC System

- **LGFCs is developing:**

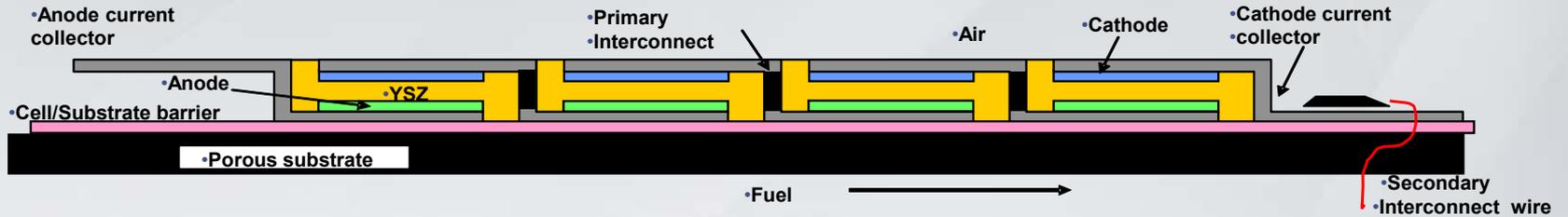
- **Cost competitive distributed energy solution**
- **Potential net-AC electrical efficiencies in the 55%+ range**
- **Very low environmental impact, quick wins on air quality**
- **Reliability, Performance, Durability, Cost, & Functionality**



Vision of fuel-in to power out



Integrated Planar (IP) SOFC



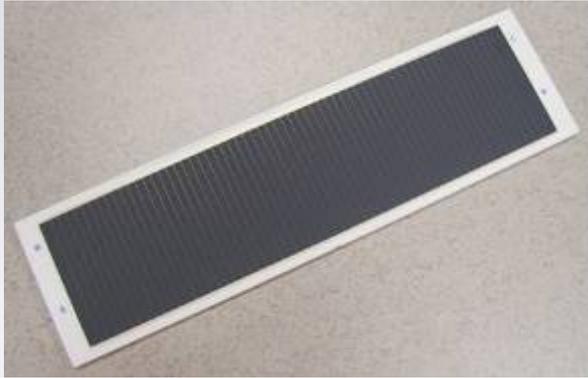
- IP-SOFC operates at high voltage, low current
- Narrow cell pitch reduces Ohmic losses
- Extruded substrate with screen printed layers



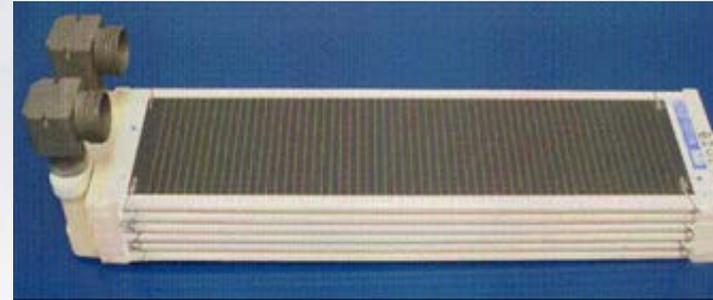
Via-based interconnect design

LGFCS Technology - recap

Tube assembly



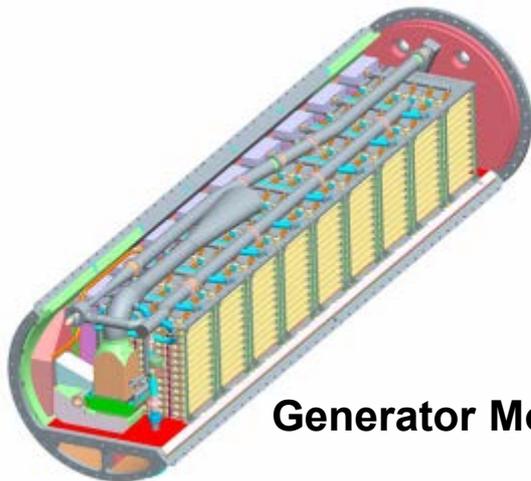
Bundle assembly



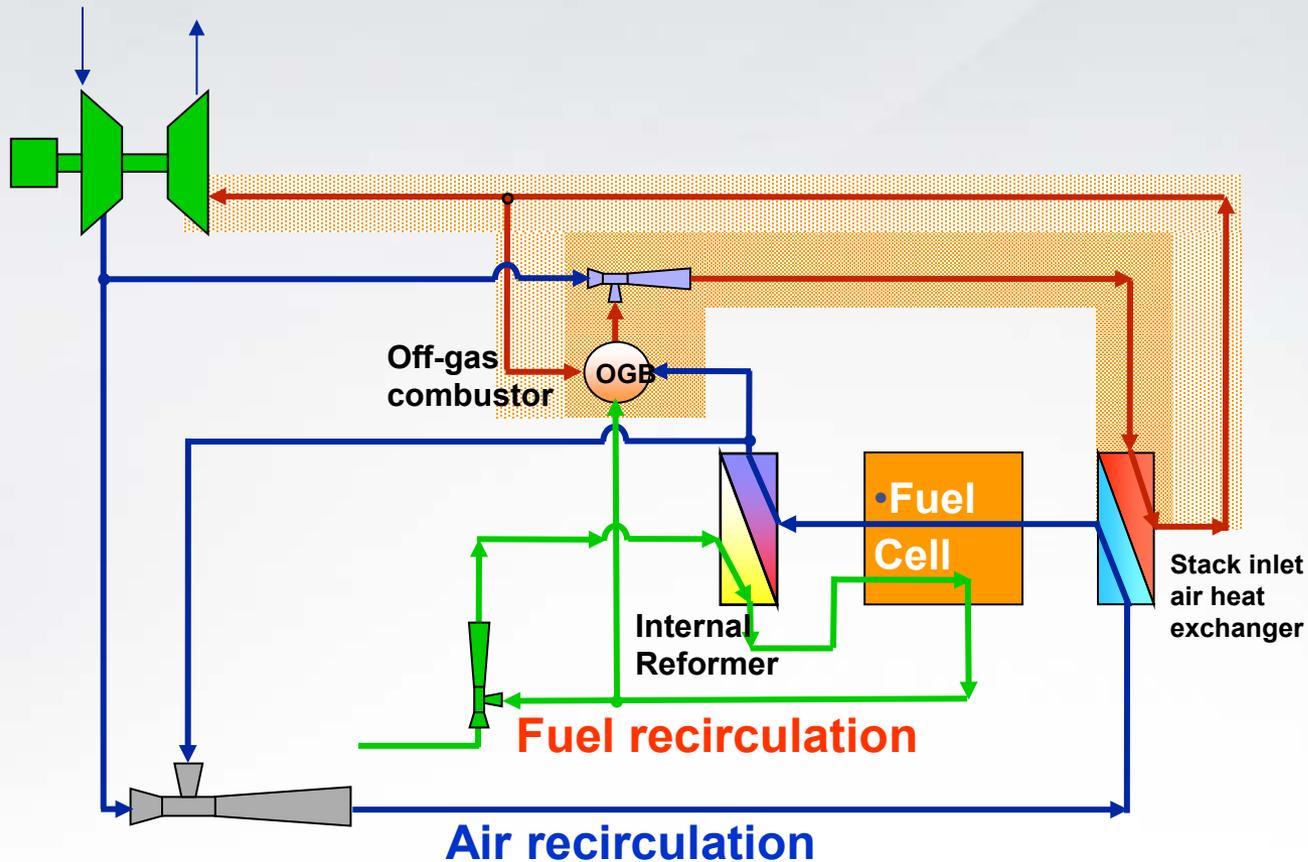
Block assembly



Generator Module

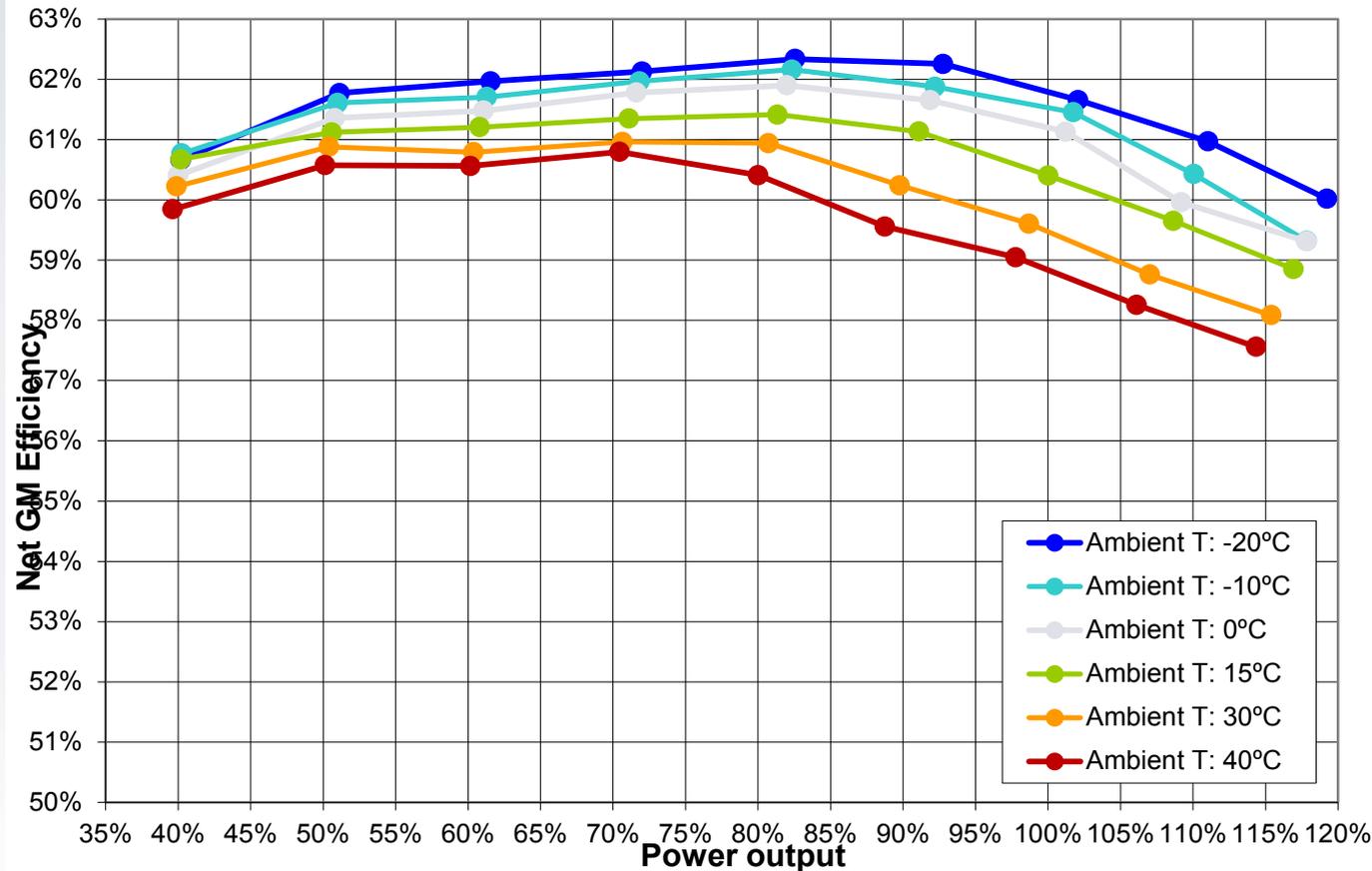


Key Features of the System-Cycle



- Pressurisation to improve power density and performance
- Anode recycle to allow for internal natural gas reforming
- Cathode recycle to minimise components' size and cost
- Ejectors to drive recycle loops
- Combustion products confined in small volumes
- Improved durability of system components

Chemistry dominates cycle so part load and ambient have little effect on efficiency



Indicative of the underlying capabilities of current technology. At EIS we may optimise the product differently or limit part load

Challenges to overcome

- **High availability >85%**
- **High reliability >95%**
- **Materials with life and performance which achieve reliability**
 - **Ceramic materials, joints, insulation**
 - **High temperature metals**
- **Chrome contamination from steels**
 - **Can have detrimental impact on fuel cell itself**
 - **Long life enclosures avoiding this detrimental effect are required**
- **Deliver: Cost, Durability, Performance, Reliability, Functionality**

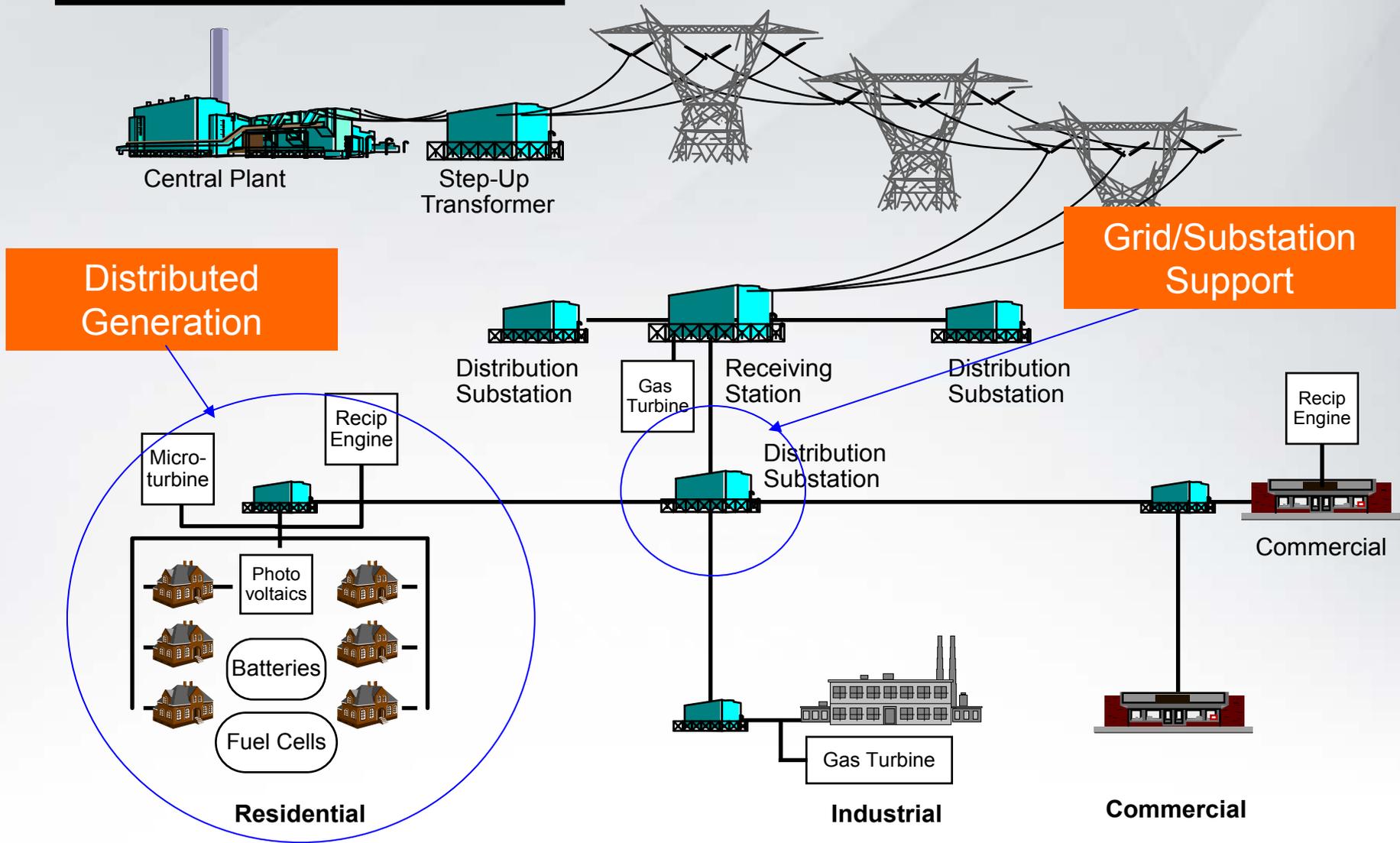
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Market Rationale

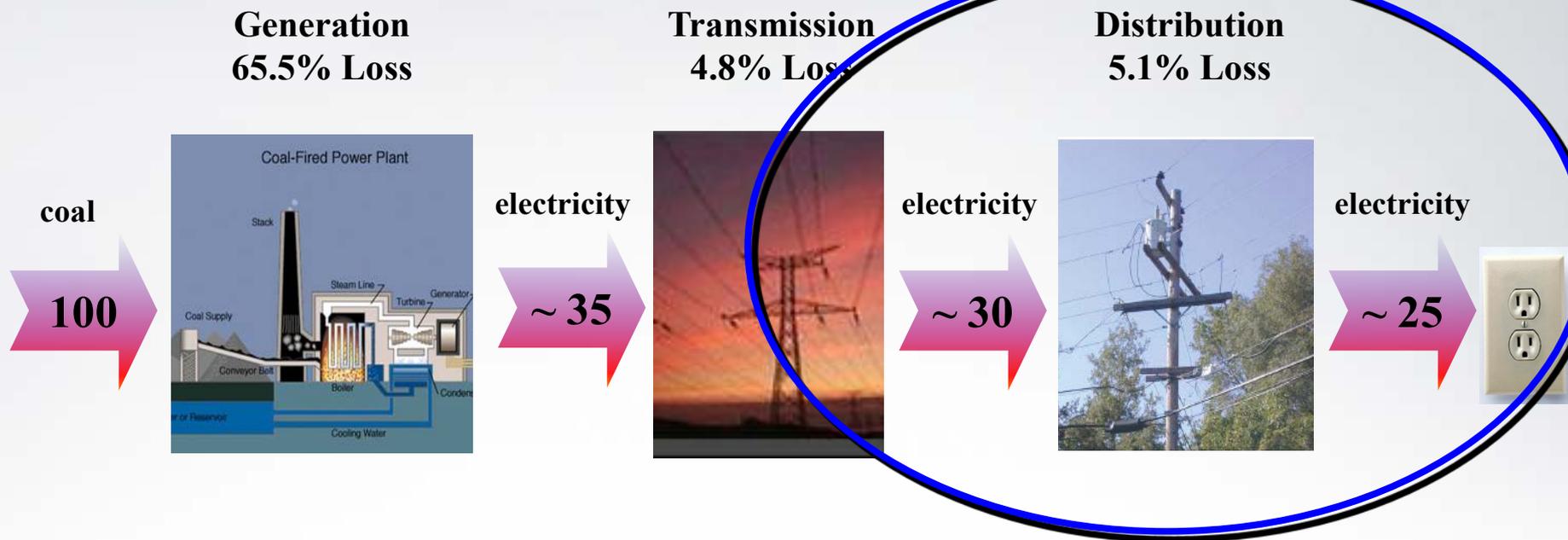
- **Electricity demand is increasing, creating a robust market for new power generation technologies**
 - Forecast 2-3% annual growth over next 25 years
 - c.300GW's for N.America alone...retirements & new build
- **Increasingly more difficult for central power to cope with a dynamic regulatory environment**
 - Air emissions and electricity transmission constraints
 - >\$2M/mile for new transmission facilities
 - Permitting challenge for new central power stations
 - Impacts the investment decision process...managing financial risk per project
 - \$2-3B for central generation vs. \$2-3M for distributed MW fuel cell system
- **Utility market pull and demand is present...**
 - Interest and dialogue with >40 large energy companies globally

Initial Applications



Why Electric Utilities are Interested...

Conventional Power System with Central Generation



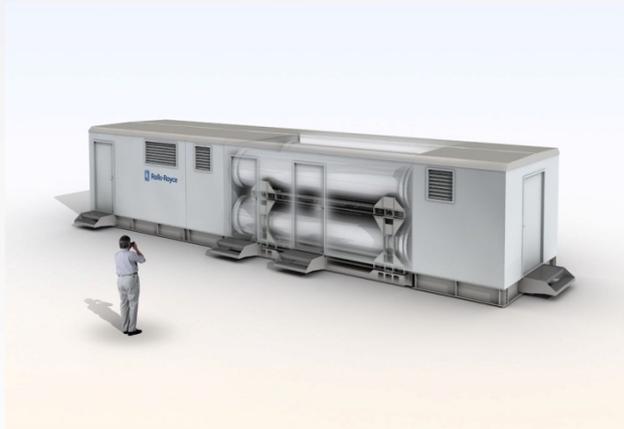
Why Electric Utilities are Interested...

Power System with Distributed 1MW Fuel Cell System

Generation (near point of load)
40% Loss

NG

100



electricity

~ 60

Distribution
5.1% Loss



electricity

~ 55



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Acknowledgements

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Thank you!

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