To enable the generation of efficient, low-cost electricity with intrinsic carbon capture capabilities for:

- **Near term: Natural gas-based distributed generation**
  - 100 kWe – 1 MWe

- **Long term: Coal and natural gas utility-scale applications with Carbon Capture and Sequestration (CCS)**
  - 10 MWe – 50 MWe

*Based on progressively larger natural gas-fueled validation tests, MWe-class DG SOFC Power Systems that are cost-competitive with existing DG technologies are envisioned circa 2020*
## Solid Oxide Fuel Cells

### Technology Area

#### Key Technologies

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<th>Cell Development</th>
<th>Core Technology</th>
<th>Systems Development</th>
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### Research Focus

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**Challenges**
- Increase power density
- Lower degradation
- Reduce costs

**Approach**
- Innovative materials
- Increase cell area
- Automation

**Challenges**
- Thermal gradients
- Flow maldistribution
- Lower cost

**Approach**
- Modeling
- Robust/low cost materials
- In-stack fuel reformation

**Challenges**
- Component integration
- Complexity
- Operating strategy

**Approach**
- Systems analysis
- Progressively larger system tests
- Multiple demonstrations

**Challenges**
- Reduce degradation
- Improve reliability
- Lower cost

**Approach**
- Modeling
- Compact design
- Advanced manufacturing
SOFC Program
Technology Development Schedule

2015
50 kWc POC
- Thermally self-sustaining
- Fully integrated system
- TRL 6
- COMPLETED

200 kWc POC
- Thermally self-sustaining
- Natural gas
- TRL 6
- COMPLETED

400 - 500 kWc Prototype Test(s)
- Natural gas
- Fully integrated system
- TRL 7
- One awarded; two additional planned

2020

MWe Demonstration(s)
- Natural gas
- CCS
- TRL 8

Cell and Core Technology Development
- Cell power enhancement & reliability
- Modeling & systems analysis

2025

Commercial DG Systems
- Natural gas
- Privately funded
- TRL 9

50 MWe Utility-scale Demonstration(s)
- First-of-a-kind
- CCS
- TRL 8

2030

10 MWe Demonstration(s)
- IGFC/NGFC slipstream
- CCS
- TRL 8

Cell and Core Technology Development
- Innovative stack design(s) & balance-of-plant
- TRL 2-5
Test progressively larger stacks/systems
Explore new cell and stack concepts to significantly undercut cost targets
Continue R&D to reduce cost, improve performance, and improve reliability
## SOFC Reliability Challenges

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<th>Technology</th>
<th>Topic</th>
<th>Issue</th>
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| **Cells**  | Manufacturing/QC | • Manufacturing reliability/quality control issues.  
• Non-destructive tests  
• Cell-to-cell variability |
|            | Chemical Instability | • Long-term microstructural/chemical changes in cell  
• Phase separation |
| **Stacks** | Manufacturing/QC | • Dimensional tolerances |
|            | Contacts | • Electrode-Interconnect contact variability and degradation |
|            | Seals | • Seal failure  
• Corrosion of brazes/welds  
• Delta T effects |
| **Systems** | Electrode Contamination | • Cathode poisoning (e.g., Cr) |
|            | Anode Redox | • Anode redox expansion/contraction |
|            | Commissioning | • **BOP components**  
• Thermal management |
SOFC Power System

Contribution to System Cost
- Fuel Cells: 40%
- Fuel Cell Module: 30%
- Balance-of-Plant: 30%

Contribution to Cell Performance
- Cathode: 60%
- Anode: 20%
- All other: 20%

Figure courtesy LG Fuel Cell Systems
Fuel Treatment
- Reformer/processor
- Natural gas desulfurization
- Coal contaminants
- Liquid fuels
- Anaerobic digester gas

Heat Exchangers/Recuperators
- Low cost
- Compact
- Low pressure drop

Blowers
- Fuel (compressor)
- Air
Issues & Concerns
- High temperature sensors
- Controls (steady-state and transient)
- Metering devices (steady-state and transient)
- Monitoring devices

Other
- First-of-a-kind devices
- Purpose-specific components
- Turbo-machinery
- Anode/cathode poisoning from BOP components
- Insulation