Roll to roll advanced materials manufacturing lab consortium

Project ID: MN018

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2017 U.S. DOE Hydrogen and Fuel Cells Program Annual Merit Review

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Argonne NATIONAL LABORATORY | Berkeley Lab | NREL NATIONAL RENEWABLE ENERGY LABORATORY | OAK RIDGE National Laboratory

EASTMAN Business Park | Kodak

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Overview

Timeline and Budget

- Project Start Date: 10/01/2016
- FY17 DOE/FCTO Funding: $1M (for CRADA work) leveraging $4M of AMO funding
- Anticipated recipient share: $1M
- FY17 spent: $0 of FCTO

Partners

- ORNL, ANL, LBNL, NREL
- Eastman Business Park
- Industry partners as selected through open CRADA call

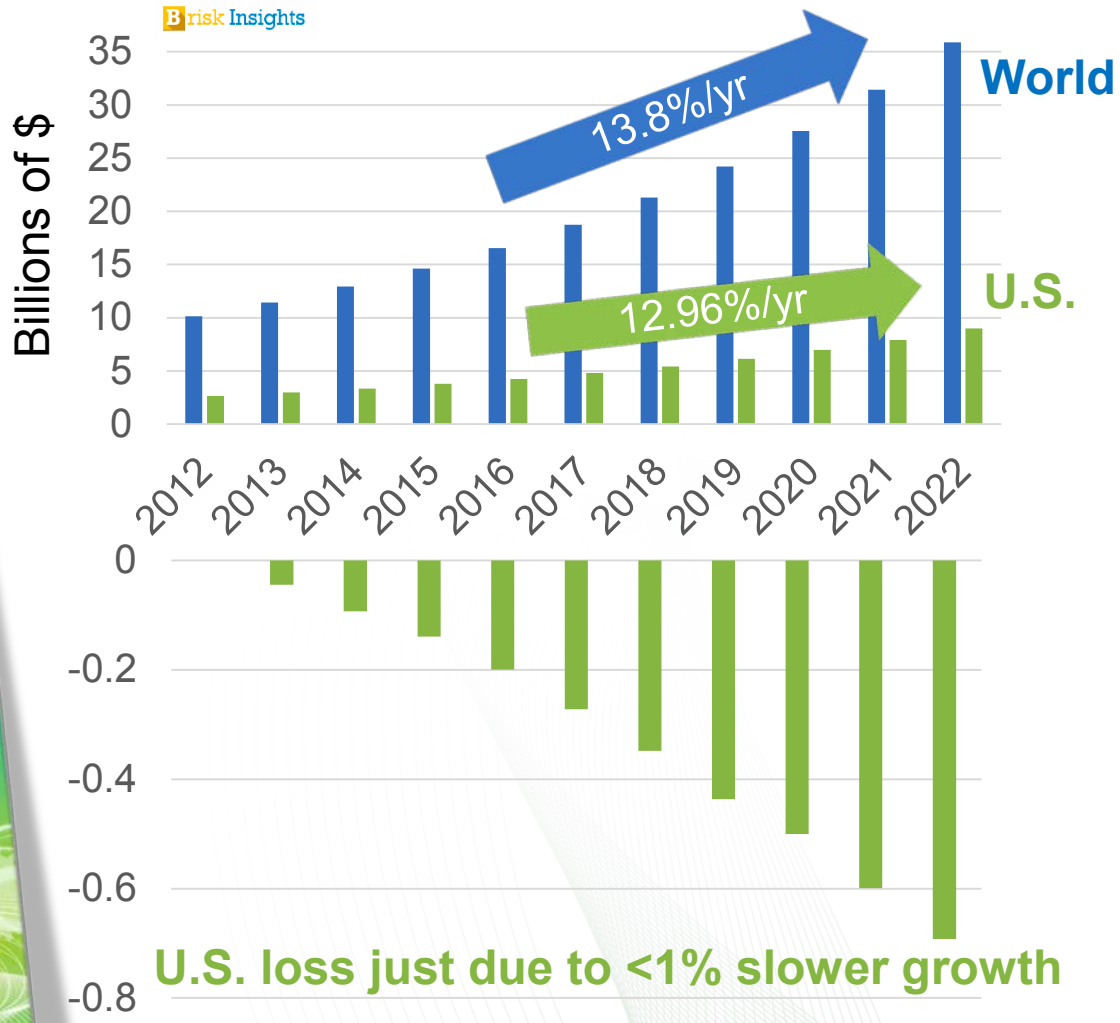
Barriers

- High cost of manufacturing
- Goals:
  - Utilize roll to roll manufacturing to reduce the cost of automotive fuel cell stacks at high volume (500,000 units/year) from the 2008 value of $38/kW to $20/kW by 2020.
  - Integrate roll to roll with fabrication and assembly processes to produce compressed hydrogen pressure vessels to enable a total onboard storage system cost of $10/kWh for widespread commercialization of hydrogen fuel cell vehicles across most light-duty platforms by 2020, with an ultimate target of $8/kWh.

Relevance and motivation
Roll to roll manufacturing development is a $10Bn opportunity for the U.S.

Business as usual will result in a minimum loss of $3.3Bn by 2022 for the U.S. economy.

Mission innovation and clean energy development could easily triple the opportunity.



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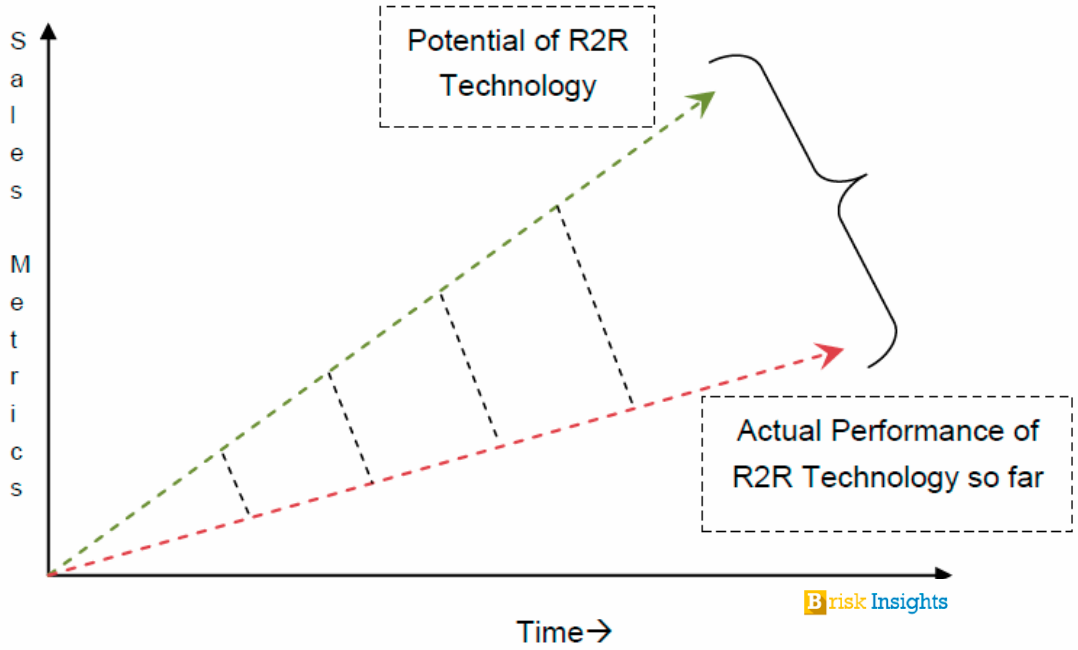
Relevance
Needs for R2R development

Enabling R2R potential

- Low manufacturing costs
- Low energy processes
- High volume production
- High throughput due to thinner membranes
- Compatible with many material platforms
- Large areas
- Varying feature sizes and dimensions



Brisk Insights recommendations:

- Establish standardized infrastructure.
- Establish parameters affecting defects control and throughput for various processes
- Establish pilot-line facilities for development and optimization of full processes
- Carefully address equipment and quality concerns

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Approach
Our current effort in short ($4M AMO/$1M FCTO)

- Lab-industry consortium will enable the United States to capture a substantial portion of this $10Bn opportunity on membranes and flexible devices
- Growth and cost reduction limitation and competitiveness limited primarily by limited R2R integration, production yield, and limitation of advanced technologies
  - **Goals depending on technology area:**
  - Increase throughput by 5x and reduce production footprint
  - Reduce energy consumption by 2x
  - Increase production yield by 2x
  - Enable substantial shift of manufacturing to the United States by assisting in the development of a domestic supply chain
- EERE as a whole will substantially benefit from AMM Consortium through integration and leveraging of solutions to program office specific applications.
- MRL2-5 tackled in core programs at national laboratories with an industrial CRADA program to move to MRL7.

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Approach
Lab-industry consortium funding structure

$5M/year from DOE – Lab industry consortium (ORNL, LBNL, ANL, NREL, Kodak) with estimated $5M cost share and $40+M leveraged investments and programs

Project Management ($100k/year)

National Lab Core Funding ($2.452M/year)

Eastman Kodak Pilot Line ($48k/year)

$2.4M/year - CRADA Project Solicitation with 1:1 Cost Sharing for Tackling Specific Industry Problems

Consortium to Release Annual Solicitation on FedBizOpps.gov

Award annual projects to Individual Companies Based on Consortium Matchmaking

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Approach
Lab-industry Partnership started with ORNL-Kodak MOU and is spanning the network to assist commercialization

EASTMAN BUSINESS PARK – FROM POC TO COMMERCIAL SCALE

- Extensive suite of tools to assist small companies
- Key set of development apparatus to conduct early and mid-stage pilot work.
- Technical resources in IP friendly manner
- Scale-up through full manufacturing

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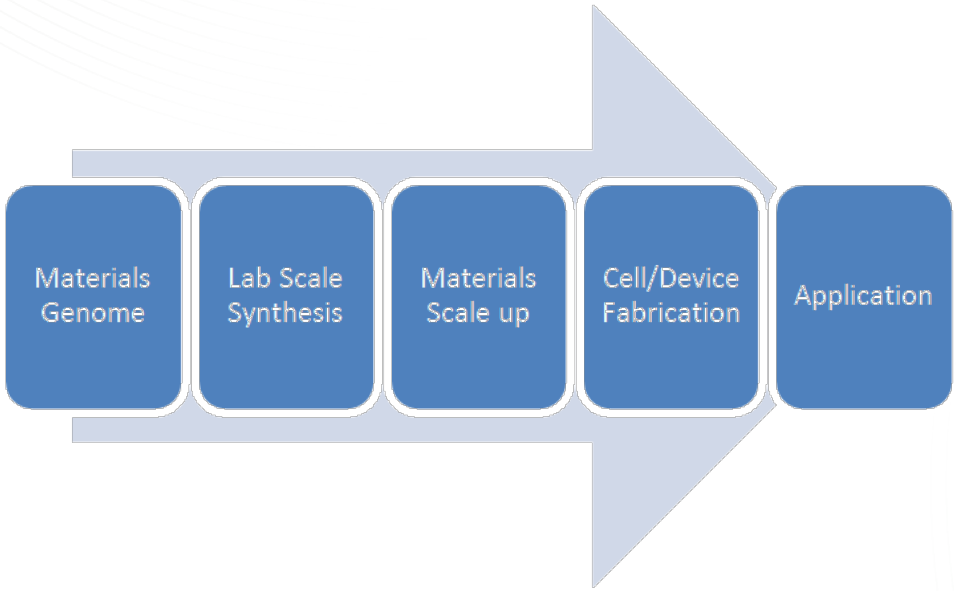
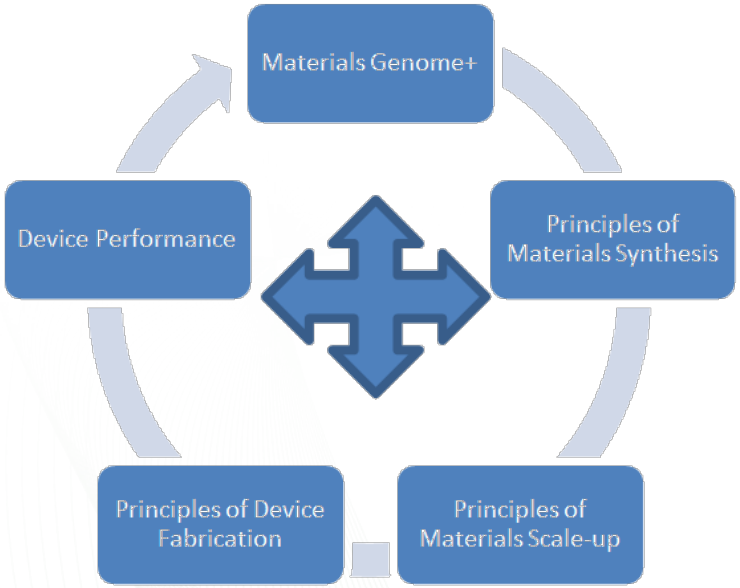
4 lab consortium changes linear approach to AMM type approach for process development





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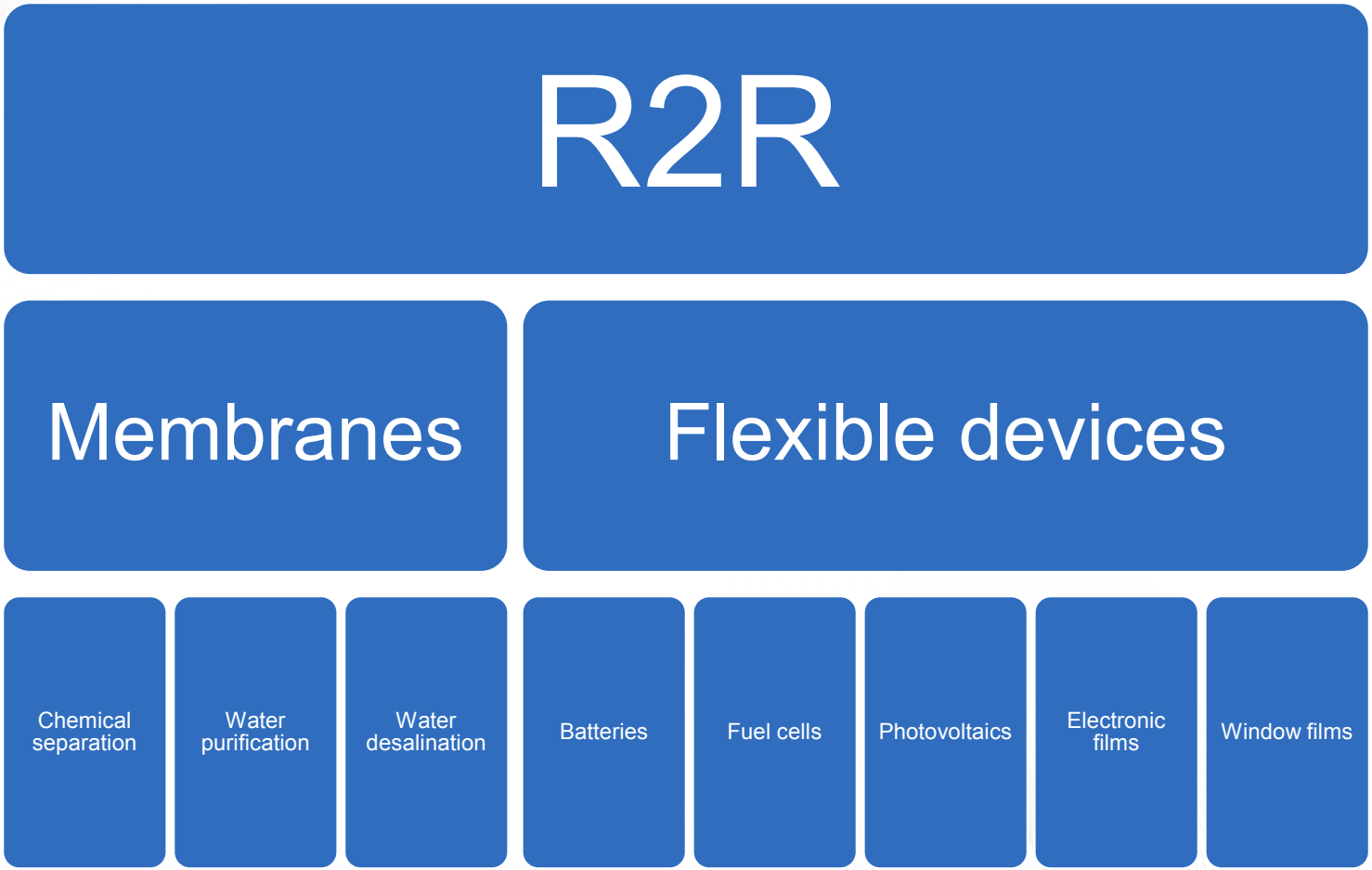
CRADA solicitation selection process

- FedBizOps solicitation
- Pre-negotiated CRADA with no negotiation with industry
- Short response time from industry
  - Selection criteria
    - MRL level and potential change in MRL due to proposed barrier being removed
    - Technology alignment with EERE and consortium
    - Application of primary metrics of success: Throughput, energy, yield
- Recommendation for funding provided to DOE for final selection
- 10-18 month execution on CRADAs

Key applications for investments by DOE



Two examples in numbers

Batteries

- Baseline technology cell cost
  - 2.5x of target of $100-125/kWh (with state-of-the-art materials and processing)

Fuel cells

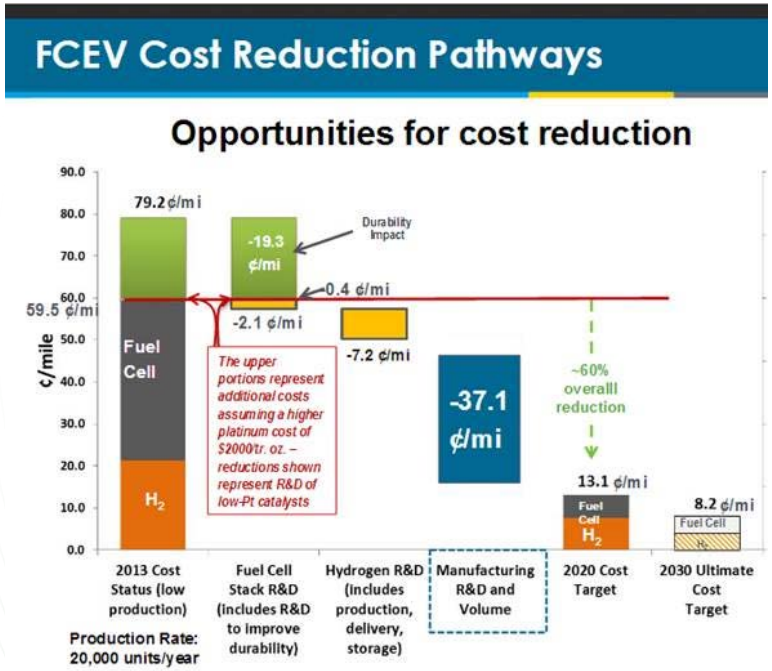
- Polymer electrolyte fuel cell stacks
  - 10x of target of $30/kW (in today's volumes without novel HV-R2R manufacturing)

Novel R2R manufacturing technologies will enable cost reduction while VTO/FCTO investments in new materials and electrodes increase energy density, power density, and reliability.

Fuel cells/Electrolysis

- Status:
  - R2R is the only manufacturing process platform that will meet cost and volume targets
  - R2R enables conversion of multiple dissimilar materials into a multi-layer cell
  - All DOE-sponsored cost analyses for high volume production of MEAs/cells assume R2R processing.
- Cost reduction need: 60 cents/mile in 2013 to 13 cents/mile in 2020

- Barriers:
  - Registration
  - integrated gasketing and multi-layer structures
  - proving-out low-Pt concepts
  - in-line quality control
  - demonstrating different layer structures at high volume
  - controlling ionomer distribution in the electrode as a function of process parameters
  - understanding material-process-performance relationships
  - understanding effects of process variations
  - increasing throughput
  - increasing width



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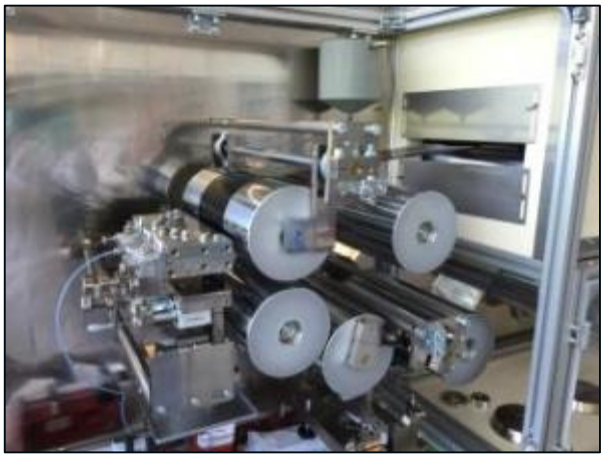
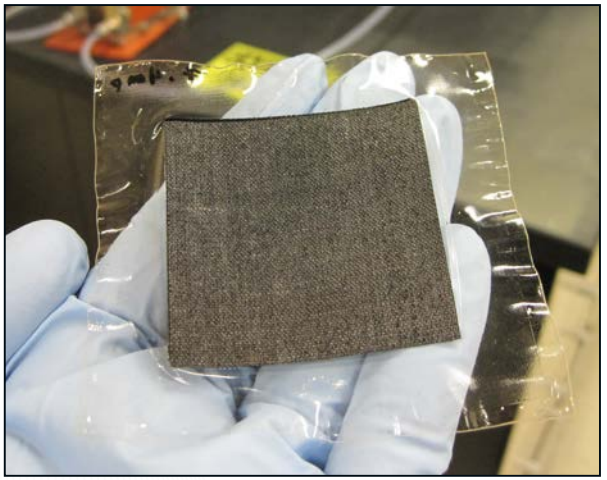
Fuel Cells core lab project: background

- Gas diffusion electrodes (GDE) are recently becoming of more interest in the industry as an alternate or possibly combined fabrication pathway for MEAs
  - GDEs entail a different set of variables that may provide improved performance and lifetime in some cases
- Fabrication of MEAs based on GDEs can require different material structures than CCMs, and, for scaling of GDE-based MEAs, this means potentially different process techniques and conditions
  - An additional layer of ionomer is often required between the GDE electrode and membrane
- These material and process parameters need to be understood and optimized for scalable processes to support increased throughput, increased quality, and reduced cost for high volume production of MEAs

FC Core Lab Project – All Tasks

1. [NREL] Explore phase-separation and other single-coating-layer methodologies to achieve an ionomer-rich surface on the GDE electrode using slot and/or micro-gravure coating
2. [ORNL] Explore dual-slot coating of electrode/ionomer to achieve a similar structure
3. [LBNL] Develop and provide flow visualization and process modeling under conditions relevant to the processes being explored by NREL and ORNL of single and bi-layer electrode ink structures, with a focus on particle-ionomer interactions
4. [ANL] Provide USAXS characterizations of inks under different ultrasonic and shear mixing conditions
5. [ANL] Provide high-throughput exploration of ink synthesis parameter space, as necessary, based on initial formulation studies at NREL and ORNL
6. [ANL] Provide nano- and/or micro- x-ray tomography of coated electrodes
7. [ORNL] Provide high-resolution microscopy of coated electrodes
8. [NREL] Make MEAs from the GDE sheets (made in tasks 1 and 2) using standard methods
9. [ORNL] Explore roll lamination of GDE sheets (made in tasks 1 and 2) and membranes using the calender
10. [NREL, ANL] Test hot-pressed and calendered MEAs for performance





Development Assistance Opportunity for Roll-to-Roll (R2R) Advanced Energy Materials Manufacturing – FedBizOpps.gov
Solicitation Number: ORNL-R2RAMM-2017-02-02

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Summary

- **Relevance:**
  - Develop roll to roll manufacturing techniques to reduce the cost of automotive fuel cell stacks at high volume (500,000 units/year) from the 2008 value of $38/kW to $20/kW by 2020.
  - Integrate roll to roll with fabrication and assembly processes to produce compressed hydrogen pressure vessels to enable a total onboard storage system cost of $10/kWh for widespread commercialization of hydrogen fuel cell vehicles across most light-duty platforms by 2020, with an ultimate target of $8/kWh.
- **Approach:**
  - Assist with lower tier research and development for technical barriers proposed by industry through a competitive CRADA process
- **Collaborations:**
  - ORNL, ANL, LBNL, NREL, Eastman Business Park, industry
- **Accomplishments:**
  - Common CRADA terms and conditions negotiated between DOE and four laboratories
  - CRADA call posted on FedBizOpps.gov – Solicitation ORNL-R2RAMM-2017-02-02
- **Future Work:**
  - Industry submission of technical proposals
  - Selection of CRADA projects
  - Negotiation of SOW and start of projects