Growing Radical Innovation from Basic Research Insights

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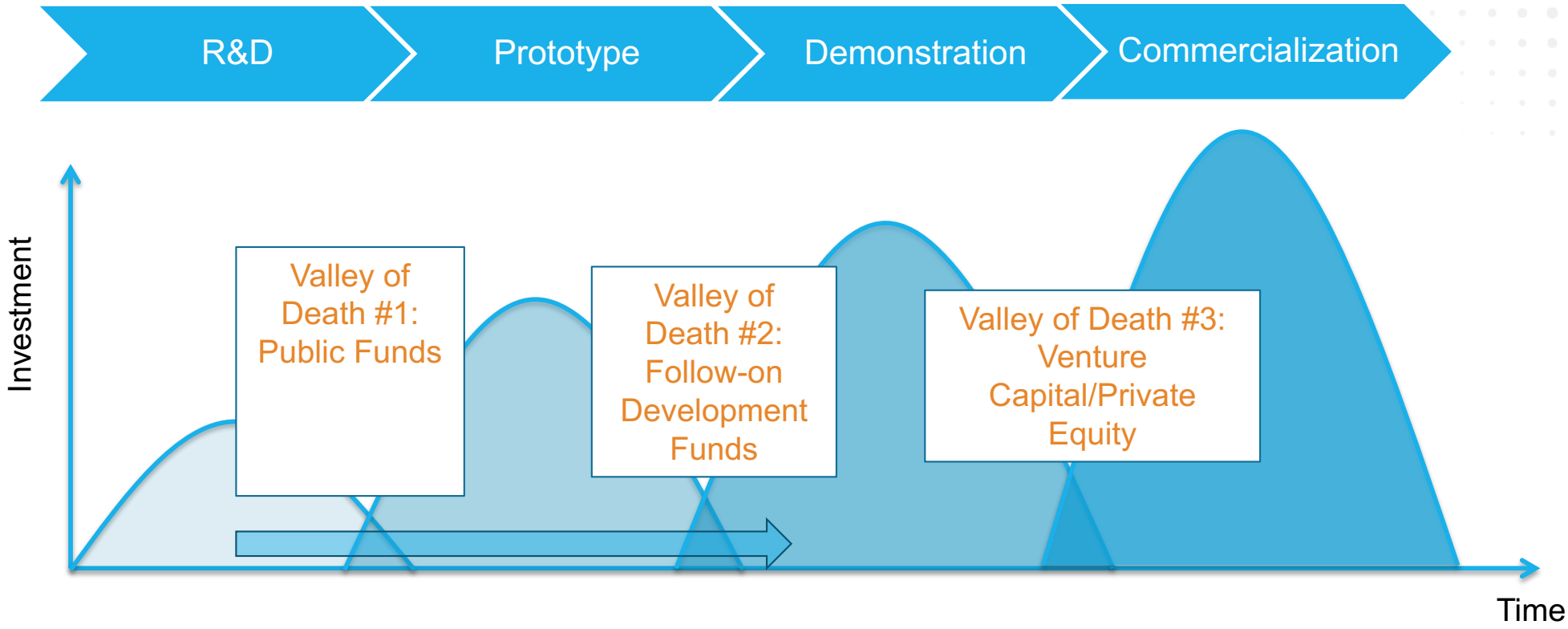
Transitions Toward Market Adoption

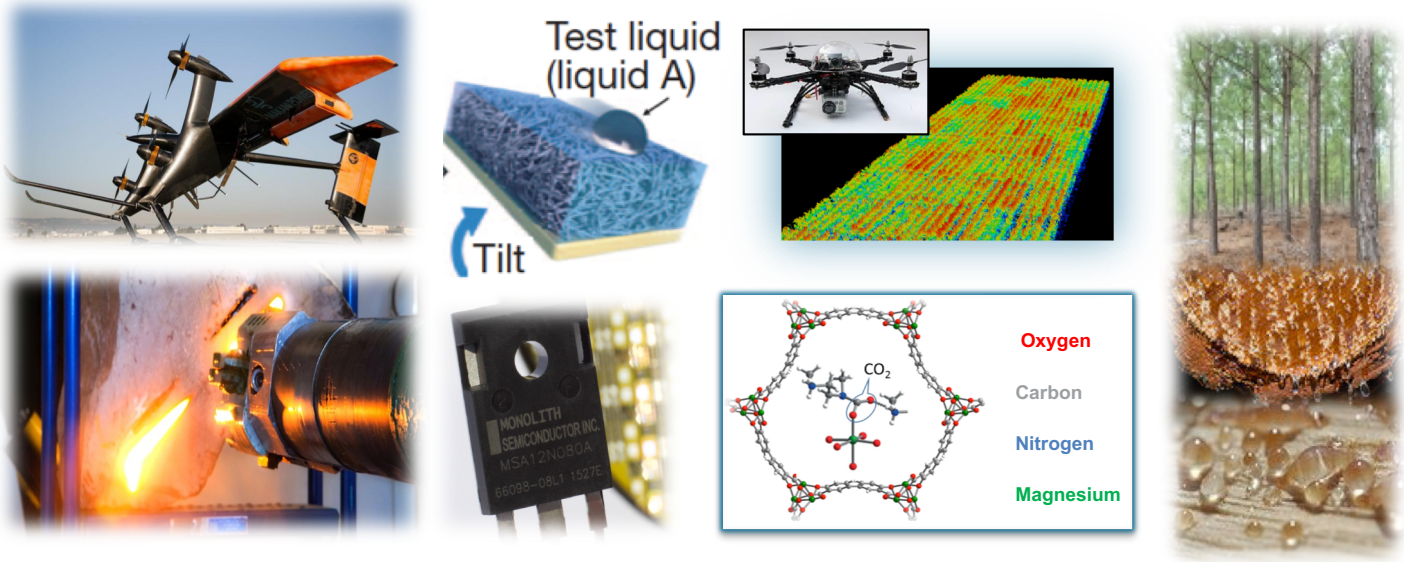


Pathways of Technology Advances

What curve will this new technology follow? Will it develop new markets in areas where standard wind is not economical? Will it disrupt the standard wind turbines market?

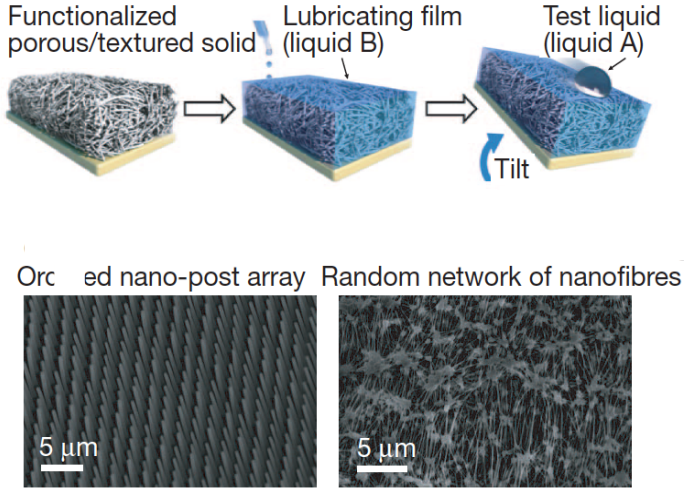
Will improved learning allow wind turbines to continue to drive down costs, and expand markets?

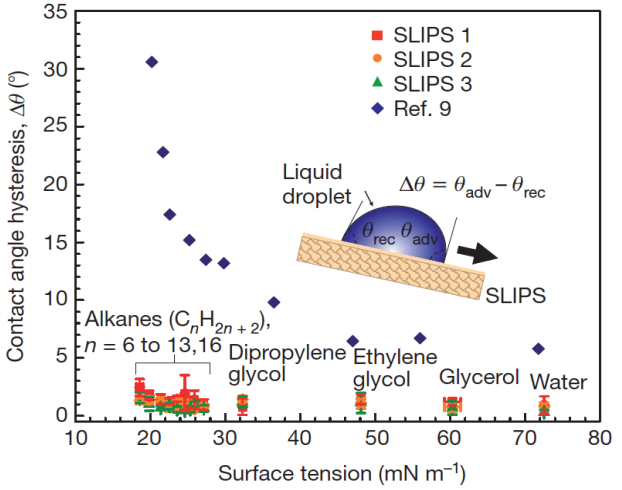
Innovation: the intersection of opportunity and application



SLIPS: Slippery Liquid-Infused Porous Surfaces

- "… instead of using [structured surfaces] to repel impinging liquids directly, systems such as the Nepenthes pitcher plant use them to lock-in an intermediary liquid that then acts by itself as the repellent surface. . . . In pitcher plants, this film is aqueous and effective enough to cause insects that step on it to slide from the rim into the digestive juices at the bottom by repelling the oils on their feet."





Wong, et. al, *Bio-inspired self-repairing slippery surfaces with pressure-stable omniphobicity*, Nature 477, 443 (2011)

SLIPS: Product Definition

Techno-Economic Analysis

Application Areas

- Refrigeration – *Evaporators*
- Waste Water Aeration - *Aeration Membranes*
- Algae Anti-Fouling - *Culture Vessels*
- Drag Reduction - *Pipelines*
- Dust Accumulation - *Photovoltaics*

Selection Criteria

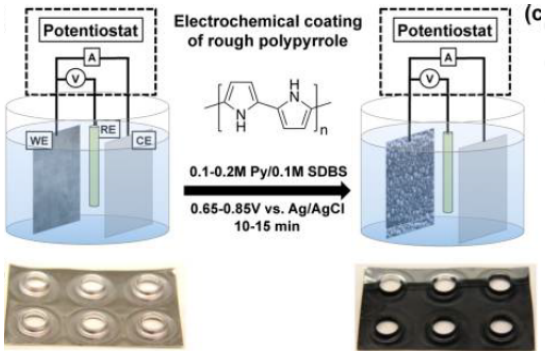
- Technical Readiness/Robustness
- Scalability of Application
- Time to Commercialization
- Customer Value Creation
- Market Size and Growth
- Regulatory/Environmental Risks
- ROI (**Return on Investment**)/Payback Period
- Supply Chain Development
- Potential US Energy Savings (annually)
- Capital Intensity

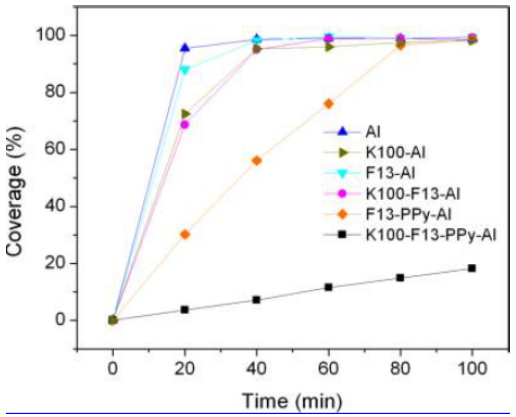
- Annual US defrost energy consumption:
  - (**supermarket cases**) ≈ 6400 GWh
  - (**residential**) ≈ 7178 GWh

SLIPS: Slippery Liquid-Infused Porous Surfaces

- Assessment: Technical Application to Ice Build-up and Defrosting
  - Development of well-adhered porous, textured surface layer
  - Development of infusion liquids that repel water, slow ice nucleation, and facilitate melting and water shedding
  - *Liquid-infused nanostructured surfaces with extreme anti-ice and anti-frost performance*, ACS Nano 6, 6569, 2012.

- Slips Results
  - Defrosting at 5°C
  - Reduces defrost time by 22%
  - Reduces total defrost energy by 38.2%
- Commercialization
  - Scalable electrochemical process
  - Established supply chain for materials





Ice formation at -2°C and 60% RH

SLIPS to AdaptiveSurface Technologies

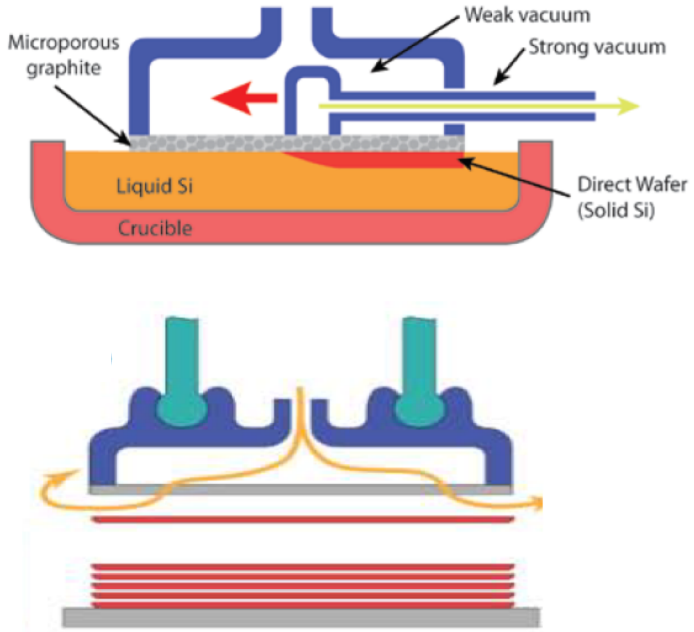
- **Start-up company SLIPS technologies in 2014** http://www.slipstechnologies.com
- Private sector funding by 2014: $3 million from investors including BASF Venture Capital and private investor/entrepeneur H. Wyss. http://www.bizjournals.com/boston/blog/startups/2015/03/liquiglide-competitor-slips-technologies-targets.html?page=all
- Private sector funding 2017: Series B investment, $5.65M from Wyss, BASF, Anzu Partners, Mass. Clean Energy Center

2017: Changed name to AdaptiveSurface Technologies http://adaptivesurface.tech/

2018 Product Releases

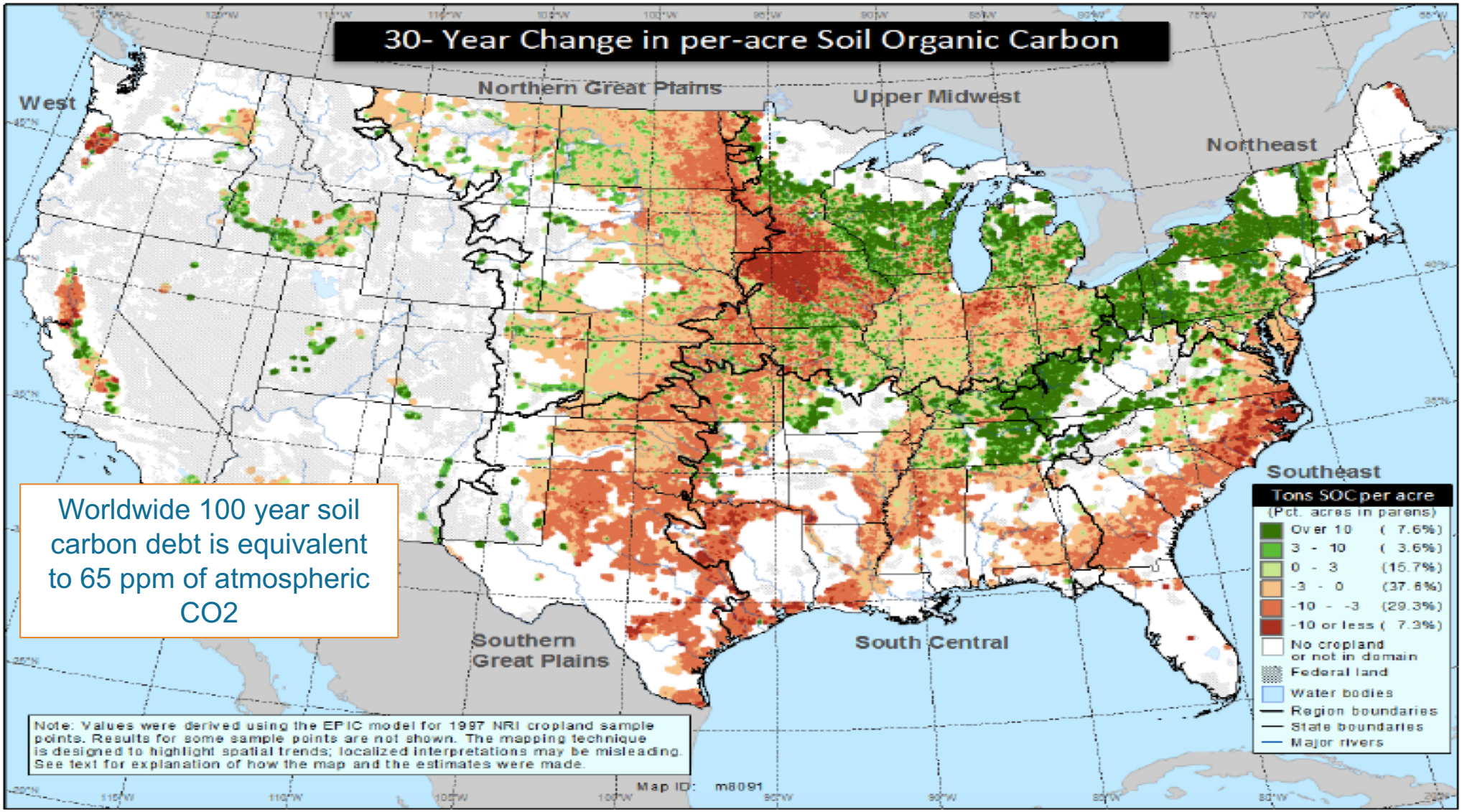
1366 Vision and Timeline

Kerfless Crystalline-Silicon PV

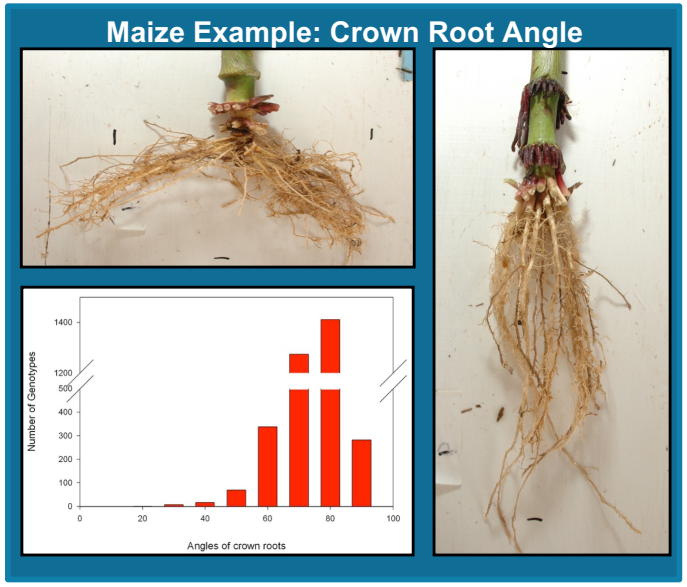


Timeline:

- **2008: Funding to Prof. Ely Sachs (MIT)/1366 from Northbridge/Polaris (Series A venture fund)**
- **2007-9: DOE pre-incubator awards**
- **2010: ARPA-E award**
- **2010: Series B funding from Northbridge/Polaris**
- **2010: Funding from GE/NRG/Conoco**
- **2011: DOE Loan Guarantee award, $150M**
- **2012: DOE/EERE Award (SunShot)**
- **2013: 25MW/yr demonstration facility**
- **2015: 20 module field test with IHI (Japan)**
- **2015: 19.1% full module efficiency demonstrated**
- **2015: 3 GW plant announced in NY, with state incentives**
- **2016: 700 MW sales agreement (Hanwha) announced, Funding (Series C) from Hanwha Solar (S. Korea) and Wacker Chimie**
- **2017: 50kW commercial PV installation, in Japan**
- **2017: DOE Loan status pending**


30- Year Change in per-acre Soil Organic Carbon
West
Northern Great Plains
Upper Midwest
Northeast
Southeast
Southern Great Plains
South Central
Worldwide 100 year soil carbon debt is equivalent to 65 ppm of atmospheric CO2
Tons SOC per acre
(Pct. acres in parens)
Over 10 (7.6%)
3 - 10 (3.6%)
0 - 3 (15.7%)
-3 - 0 (37.6%)
-10 - -3 (29.3%)
-10 or less (7.3%)
No cropland or not in domain
Federal land
Water bodies
Region boundaries
State boundaries
Major rivers
Note: Values were derived using the EPIC model for 1997 NRI cropland sample points. Results for some sample points are not shown. The mapping technique is designed to highlight spatial trends; localized interpretations may be misleading. See text for explanation of how the map and the estimates were made.
Map ID: m8091

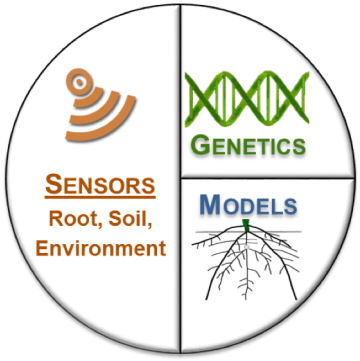
Phenotypes and Genomics



Courtesy of Jonathan Lynch, Penn State University

There is a large natural diversity of root phenotypes, which have not been addressed by breeders.

Researchers today employ "shovelomics" to evaluate crop roots.



ROOTS research teams will develop new sensors for characterizing roots systems

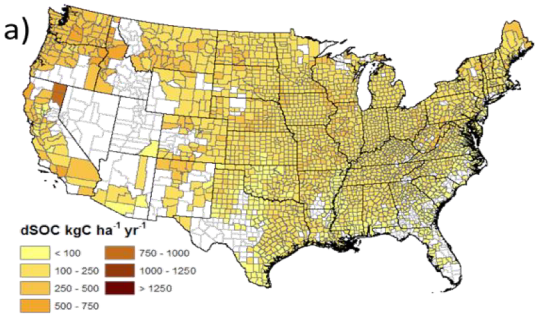
ROOTS
Soil Carbon Capture

Potential Soil Carbon Accumulation
with Improved Crop Rooting Phenotypes

arpa·e
CHANGING WHAT'S POSSIBLE

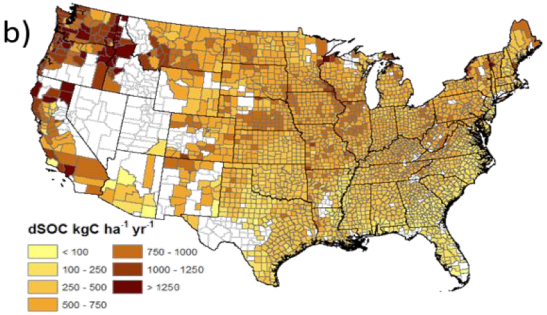
(kg C ha-1 yr^{-1} soil organic carbon over 30 years)

a)



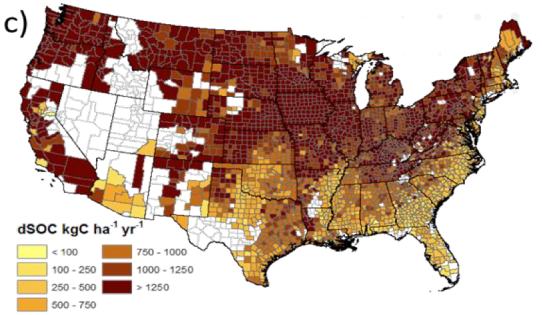
25% root C increase,
with no root root shift downward

b)



50% root C increase, w/ 20%
root shift downward

c)



100% root C increase, w/ strong
root shift downward

Cumulative savings potential by 2100 up to 61 Gtonnes CO_2 by US agricultural use

Program Metrics – monitored with quarterly milestones

Component A – Sensors		
2A.1	Instrumentation Target	Instrumentation Target: CV< 10% of root or soil property R2 >.6 ground truth value
2A.2	Technical Repeatability	>90%
2A.3	Throughput / Coverage	2 hectares with 2000 plant accessions each measured 3 times during growing season

Component B – Models		
2B.1	Improve Throughput	25%-50% improvement of throughput in field breeding.

Program Metrics – monitored with quarterly milestones

Component C – Genetics and Environment		
2C.1	Genetic Basis of Root Traits	Traits with heritability: > 0.4, or predictive models accounting for >50% of heritable variation
2C.2	Genetic (G) and Environment (E) Interaction	Quantification of GxE influence on cultivar, by measurement in at least 3 environments
2C.3	Quantify Impact	Cultivar achieves >25% validated improvement of carbon sequestration, nitrous oxide reduction, or water productivity.

ROOTS Performer Portfolio

(10 Integrated Systems Teams: Root Phenotyping, Plant Genetics, Soil Chemistry)

arpa·e CHANGING WHAT'S POSSIBLE

FULL SYSTEM TEAMS

- PennState
- The University of Georgia
- WISCONSIN UNIVERSITY OF WISCONSIN–MADISON
- The University of Nottingham

- UF UNIVERSITY of FLORIDA
- University of Missouri
- TEXAS The University of Texas at Austin
- UNIVERSITY of WASHINGTON
- DONALD DANFORTH PLANT SCIENCE CENTER
- UIC UNIVERSITY OF ILLINOIS AT CHICAGO
- Argonne NATIONAL LABORATORY

- TEXAS A&M AGRILIFE RESEARCH
- ABQMR
- NIST
- MGH 1811 MASSACHUSETTS GENERAL HOSPITAL

- BERKELEY LAB
- THE SAMUEL ROBERTS NOBLE FOUNDATION
- Subsurface INSIGHTS

- Colorado State University
- THE UNIVERSITY OF ARIZONA
- CYVERSE
- IOWA STATE UNIVERSITY
- DigitalGlobe

SENSOR FOCUS SYSTEM TEAMS

- Sandia National Laboratories
- THE UNIVERSITY of NEW MEXICO
- NEW MEXICO TECH SCIENCE · ENGINEERING · RESEARCH · UNIVERSITY

- IOWA STATE UNIVERSITY
- University of Nebraska Lincoln
- Stanford University
- CARNEGIE SCIENCE

- UHV Technologies, Inc. Perfection in Advanced Materials and Devices
- The University of Nottingham
- TEXAS A&M AGRILIFE RESEARCH
- UMASS LOWELL
- WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

- adelphi TECHNOLOGY, INC.
- BERKELEY LAB
- University of Nevada, Reno

What is changing for Energy Innovation?

- November 2015: Launch of Mission Innovation, under which 20 countries representing at least 80 percent of global clean energy research and development (R&D) budgets committed to double their governments' R&D investments in this domain over five years.
- Mission Innovation was implicitly connected with private sector commitments to provide 'patient' investments for commercializing promising clean energy technologies:
  - Oil and Gas Climate Investments (OGCI) – Ten year, $1 Bn fund
    - First investments:
      - Econics Technology – CO_2 to plastic
      - Solidia Technologies – CO_2-cured cement
      - Achates - high-efficiency opposed-piston engines
      - Carbon capture and storage demonstration
  - Breakthrough Energy Ventures (BEV) – Ten year, $1 Bn fund
    - Chosen focus areas: Grid-scale storage, liquid fuel, micro/mini-grids, alternative building materials, geothermal