PARC Overview

Hardware & Cleantech Overview

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About PARC

Founded in 1970 as Xerox PARC – Office of the Future

Recognized leader in research-based innovation

- Significant impact from the invention of distributed computing
- PARC is in nearly every Xerox product on the market today
- About 30 new businesses were created from PARC research

Incorporated in 2002 — a wholly owned subsidiary of Xerox

Developing an Open Innovation business model

- Convert advanced research to commercial opportunities
- Seed new business & growth platforms for our clients
- Commitment to strategically significant impact

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Facts & Figures

170 researchers, ~ $55 Million Annual Revenue

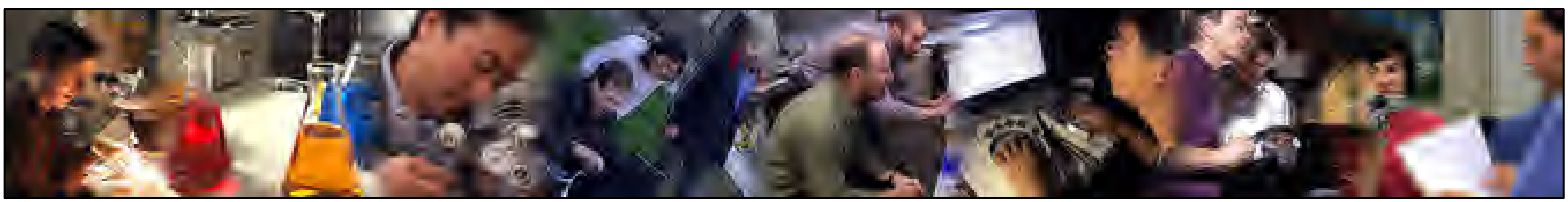
- Exceptionally broad spectrum of disciplines
- Across computational, physical, and social sciences

4 research organizations

- Computing Science, Electronic Materials and Devices, Hardware Systems, Intelligent Systems
- Cross-division projects are essential

1,800 patents and patents pending

- Average 100+ new patents per year 2000-2007



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Interdisciplinary Breadth

Information and Communication Technologies

- **Human Information Interaction**
- **Image Analysis**
- **Intelligent, Autonomous Systems**
- **Modular Systems**
- **Natural Language Processing**
- **Networking**
- **Security And Privacy**
- **Sensor Networks**
- **Ubiquitous Computing**

Electronic Materials and Devices

- **Flexible electronics**
- **Large-area Electronics**
- **Microelectromechanical Systems (MEMS)**
- **Microfluidics**
- **Optoelectronics**
- **Organic Device Design**
- **Particle Manipulation**
- **Piezo Materials**
- **Semiconductor Materials**
- **Solid-state Electronics**
- **Thin-film Technologies**
- **Optical design**

Social Sciences

- **Customer Need Discovery**
- **User-centered Design**
- **Workscapes and organizations**

Biomedical Systems (Launched 2002)

- **Rare Cell Detection**
- **High-throughput Nanocalorimetry**
- **de novo Peptide Sequencing**
- **Continuous Glucose Monitor**

CleanTech (Launched 2005)

- **Adaptive Systems**
- **Bioagent Detection**
- **Clean Water**
- **Demand Response**
- **Solar Energy**

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Electronic Materials & Devices Lab: Innovation Areas

Large Area Systems & Printed Electronics

- Nanowire devices – TFTs, solar cells
- Printed TFTs and sensors

Microsystems Technology

- MEMS and printing systems

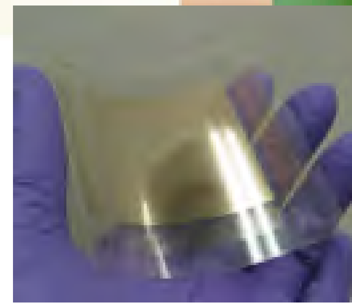
Optoelectronic Materials and Devices

- Green lasers, uv LEDs, detectors

Prototype Devices and circuits

- Poly-Si, new materials

Innovation Areas



Large Area Systems & Printed Electronics

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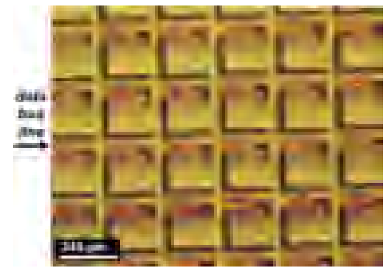
- Printed TFTs and sensors



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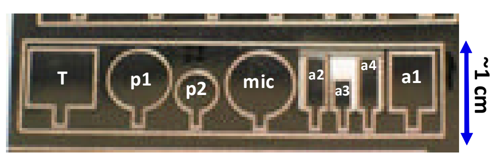
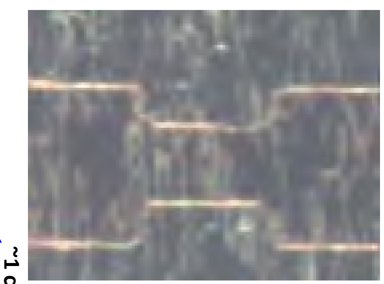
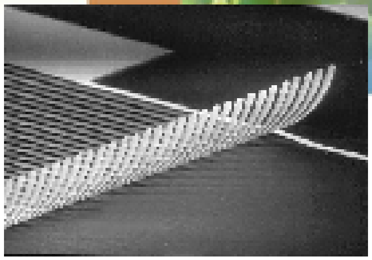


Patterned sensor areas



Nanowire TFT

Innovation Areas



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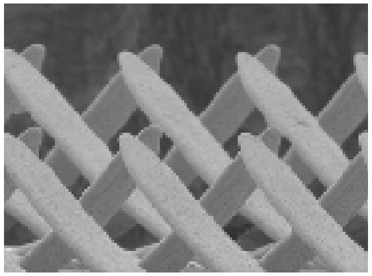
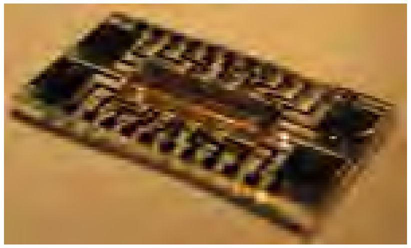


Microsystems Technology

- MEMS and printing systems

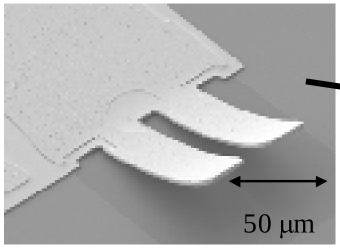
Optoelectronic Materials and Devices

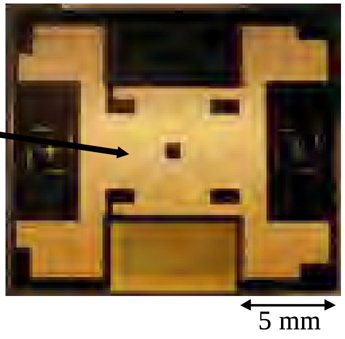


- Green lasers, UV LEDs, detectors

Prototype Devices and circuits

- Poly-Si [illegible]





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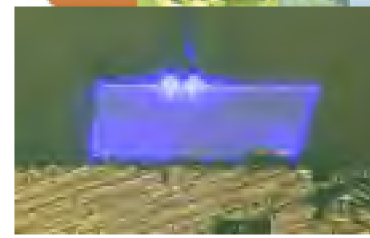
Innovation Areas



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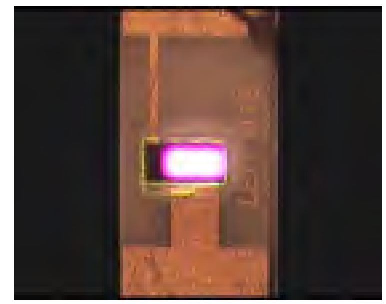


Microsystems Technology

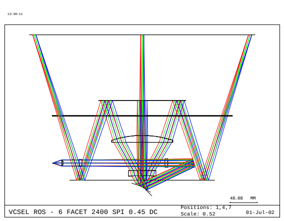
- MEMS and printing systems

Optoelectronic Materials and Devices

- Green lasers, uv LEDs, detectors, opt. systems

Prototype Devices and circuits

- Poly-Si, new materials



Innovation Areas

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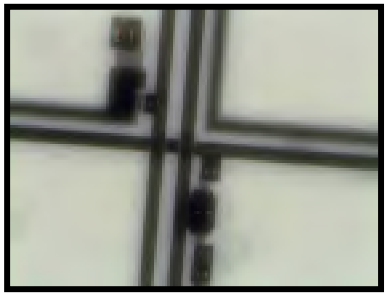

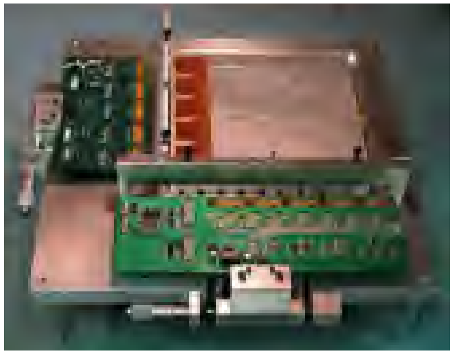

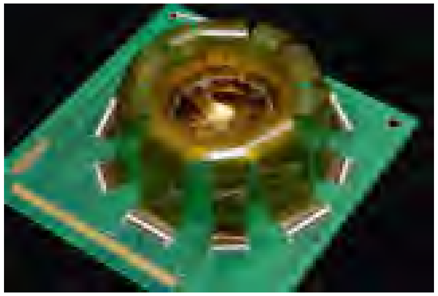

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Entry into Cleantech

- Cleantech entry in 2005 was a "grassroots," researcher-driven activity with management support
- Researchers organized a speaker series
- These events generated many new connections and insights

Program Strategy

- Leverage PARC competencies to develop manufacturable & cost-effective solutions to challenging Cleantech problems
- Engage the market early through strategic partnerships, visiting technologists & entrepreneurs-in-residence
- Maintain a portfolio balance between:
  - Short-term and long-term impacts
  - Commercialization channels

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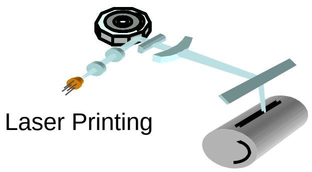
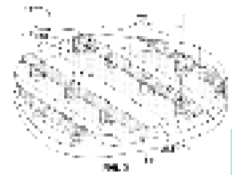
Hardware Competencies
Supporting Cleantech Agenda

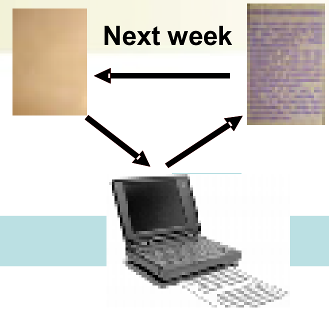


Optical Design

Solar concentrators

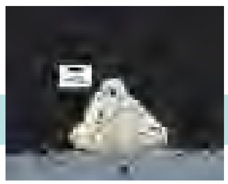


Laser processing of PV wafers

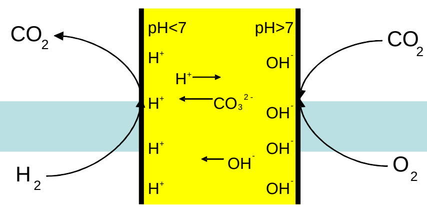


Reusable Paper

Direct Printing

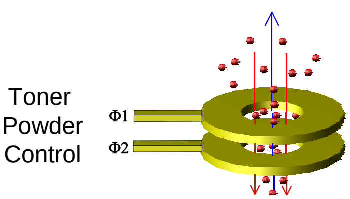


High Aspect Ratio PV Gridlines

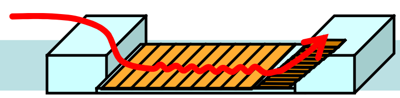


Low cost membranes for CO2 extraction

High Efficiency ThermoacousticCooling

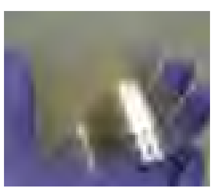


Particle Manipulation

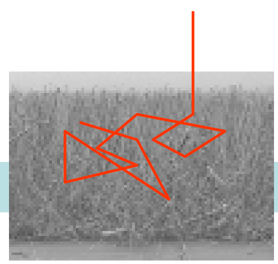


Bioagent concentrator

Membrane-less spiral flow filtration



Large Area Electronics

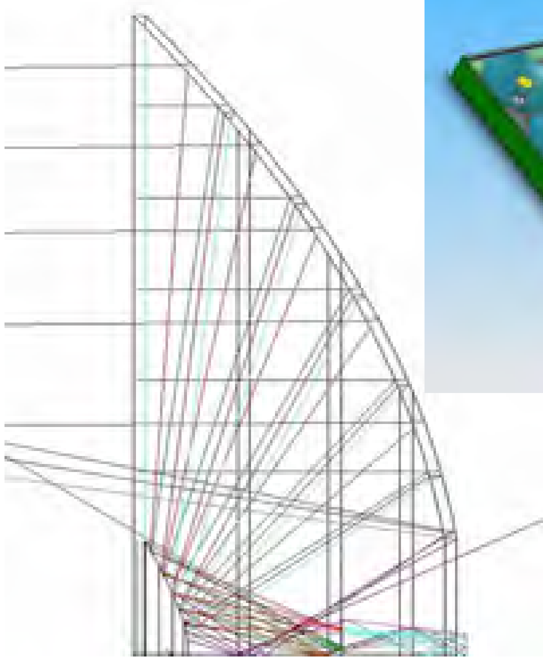


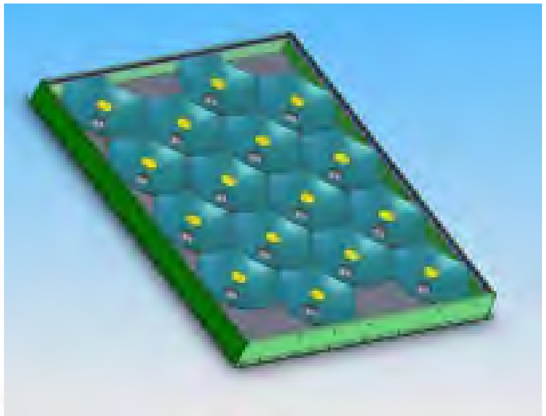
Nanowire solar cells

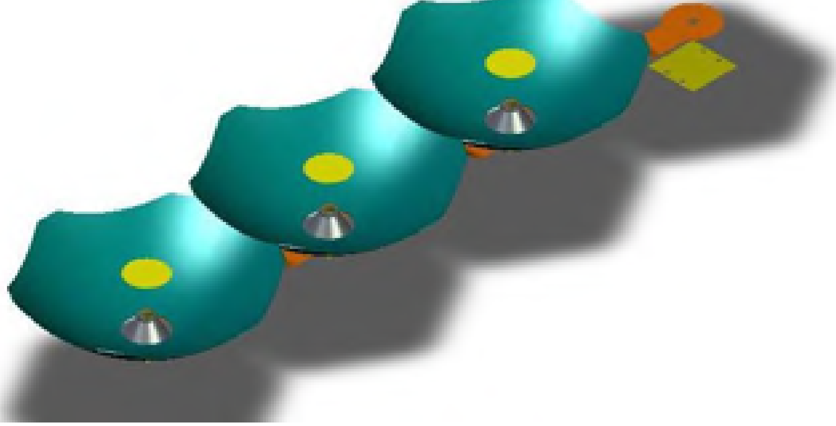
Solfocus Technology – 1st Generation

Tailored Imaging Concentrator

- 500 suns on 1cm2 Spectrolab Cells
- Passive Cooling







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500 kW Initial Deployment in Spain

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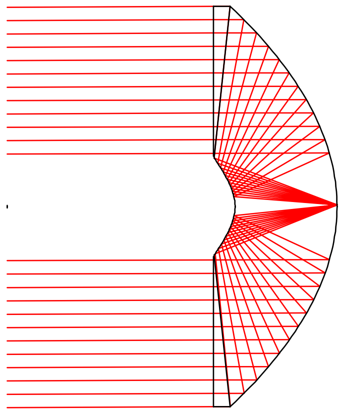
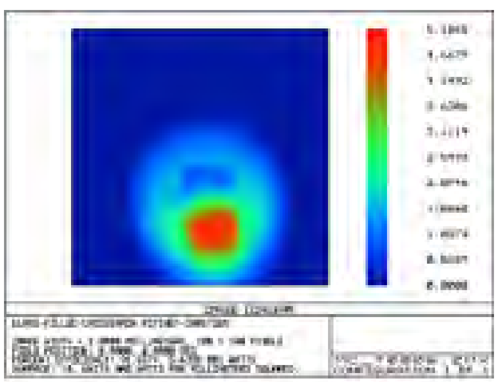
SolFocus™ Innovation Inspired by Nature

PARC Competency in Optical Design Led To 2nd Generation, Lower Cost Concentrator

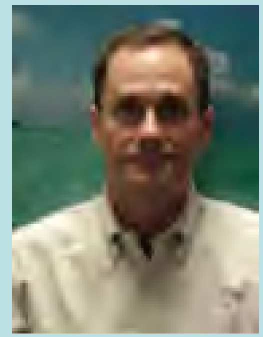




To Rapidly Increase Domain Knowledge, Bring in a Visiting Technologist

Visiting Solar Energy Technologist

Steve Shea
Previously Director of R&D
at BP Solar



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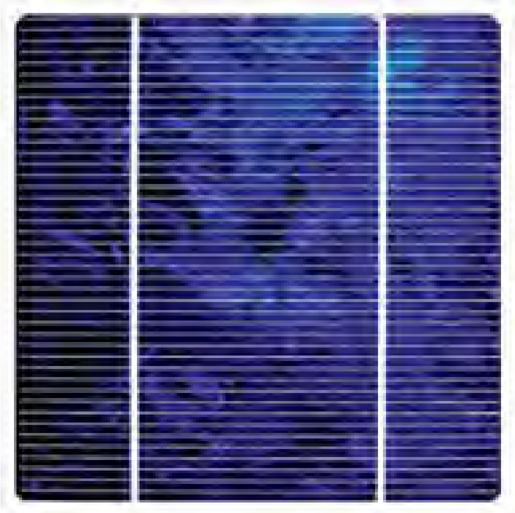
Learn about the Key Business Issues & Current Technical Approach

Efficiency of dominant multicrystalline silicon is low (15-16%) relative to potential (> 20%)

Need lower cost ($/Watt)

- Diffusion
- Edge Isolation Etch
- Antireflection Coating
- Front Silver Gridline Print
- Back Silver Print
- Back Aluminum Print
- Firing in Furnace



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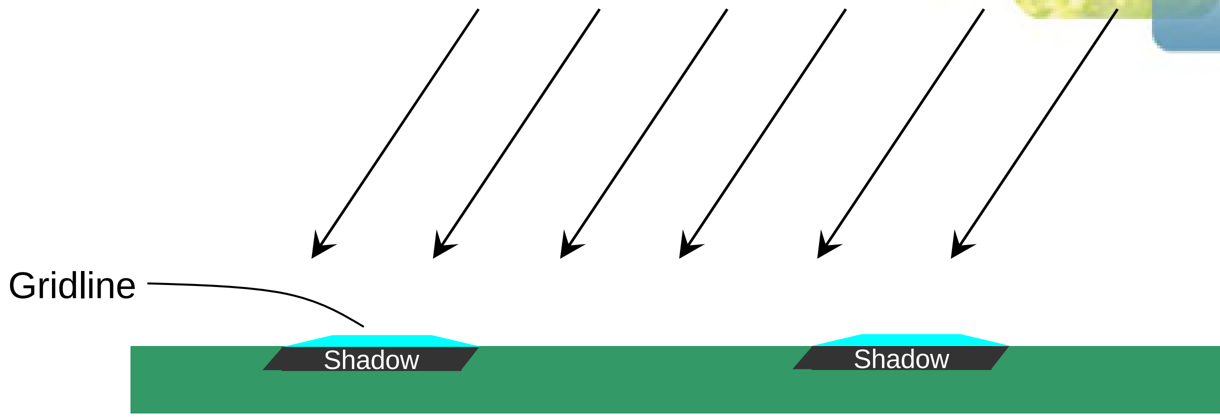
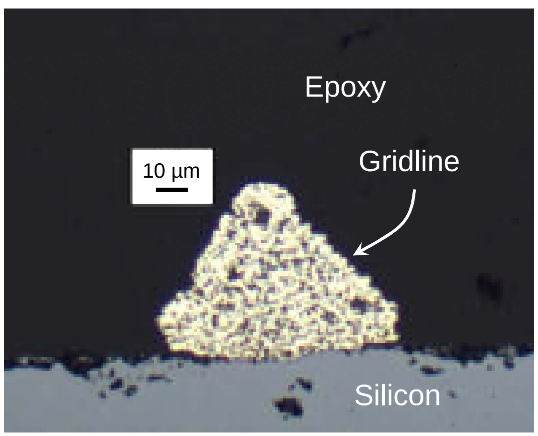
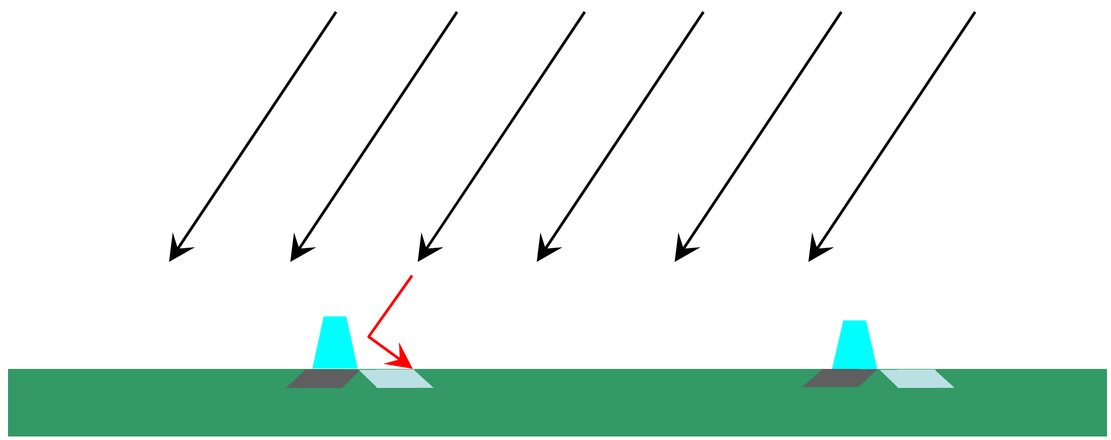
Novel Extrusion Method for Printing PV Gridlines

Screen-Printed Gridlines
Fired Aspect Ratio = 0.1





PARC Gridlines
Aspect Ratio = 0.8



Opportunity: Net Efficiency Increase of 6% Relative

100MW -> 106MW

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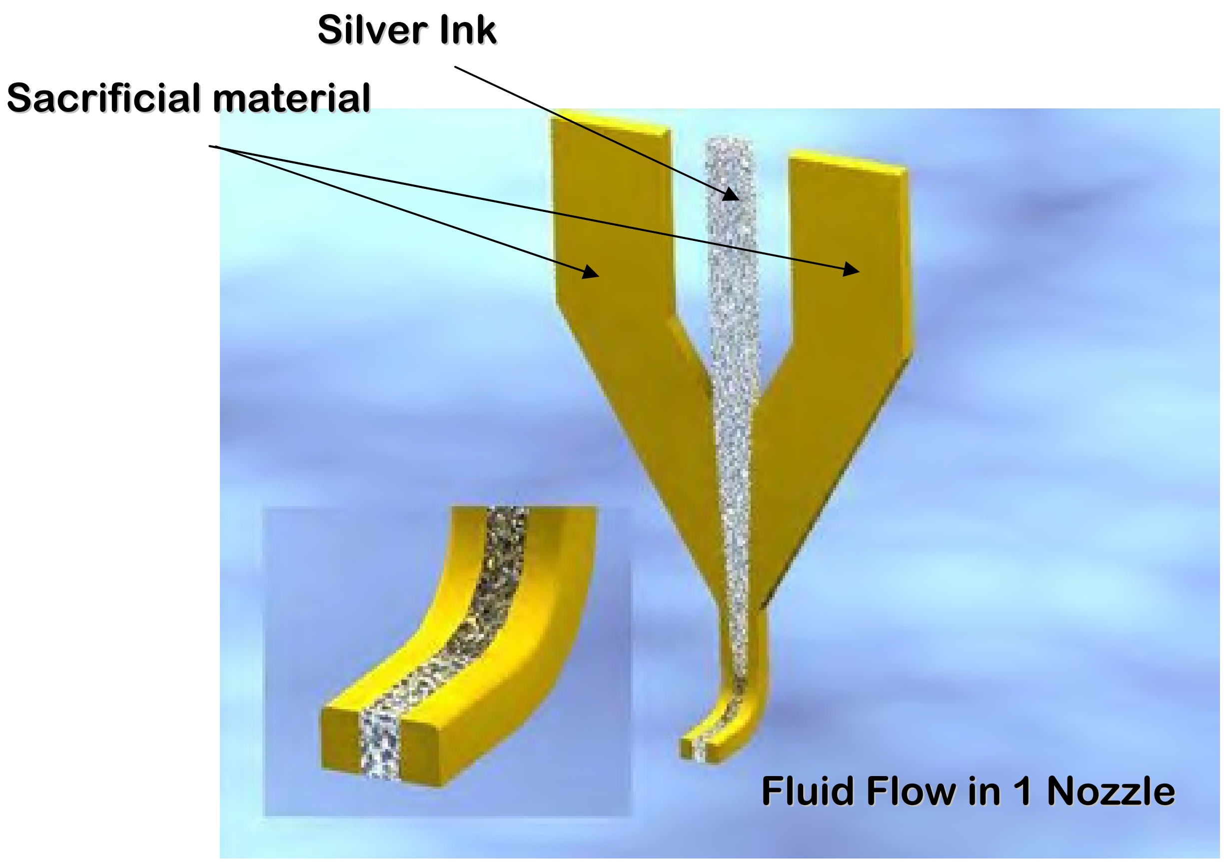
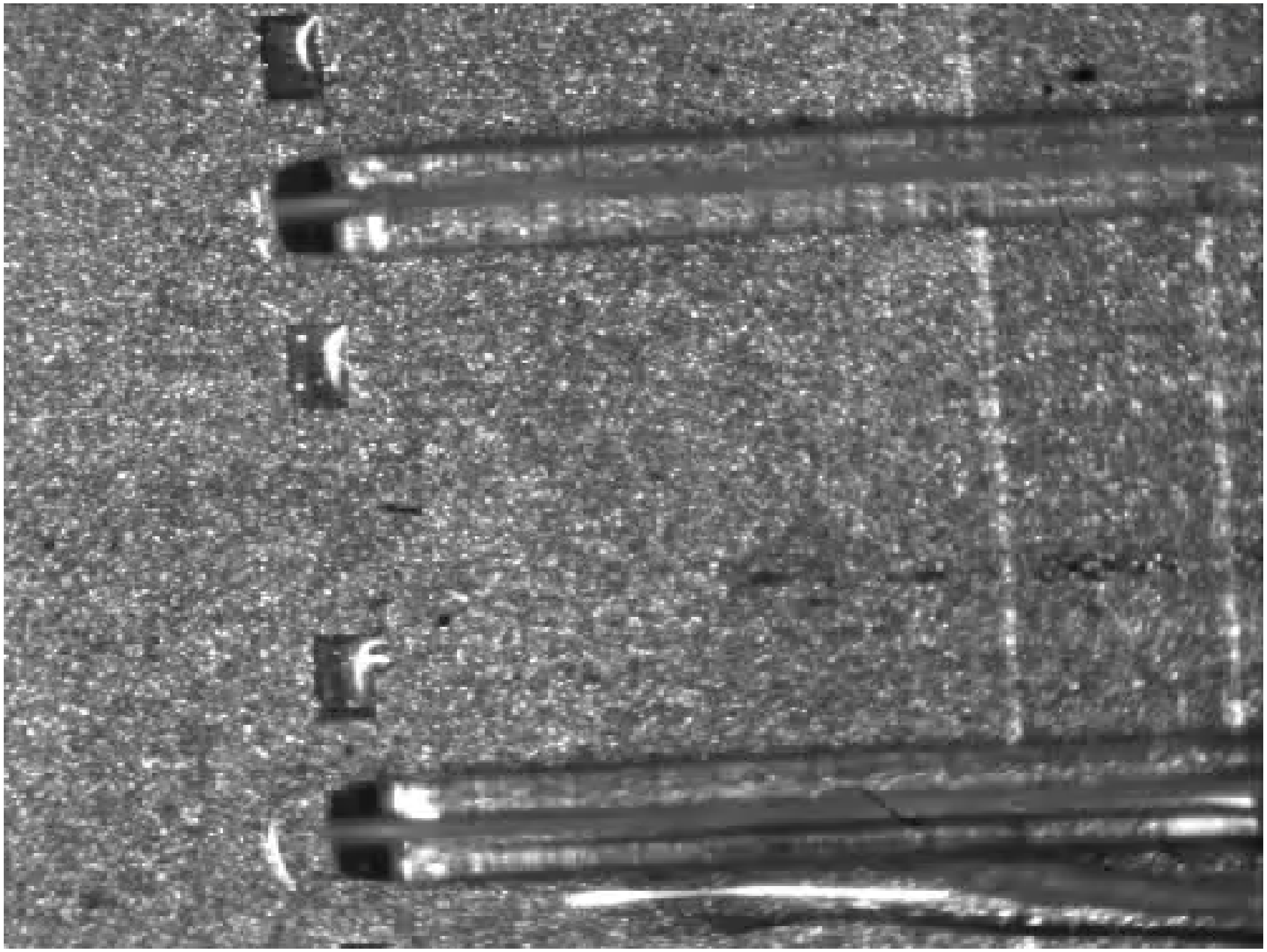
Co-Extrusion Printing
(DOE Solar America Funded)



Printhead in Operation



PARC Thermoacoustic Cooler

(ARPA-E Proposal)

		COP	Efficiency	Power	Power density
Thermoacoustic Target	**PARC**	**5**	**46% Carnot**		**64 W/kg**
Stirling	**Sunpower**	**2.5**	**30% Carnot**	**34 W**	**11.5 W/kg**
	Twinbird	**1.1**	**25% Carnot**	**40 W**	**13 W/kg**
	Global Cooling	**3**	**30% Carnot**	**120 W**	**53 W/kg**
Compression	**Maytag**	**1.1**	**17% Carnot**		
	Kenmore		**~8% Carnot**	**5274 W**	**103 W/kg**

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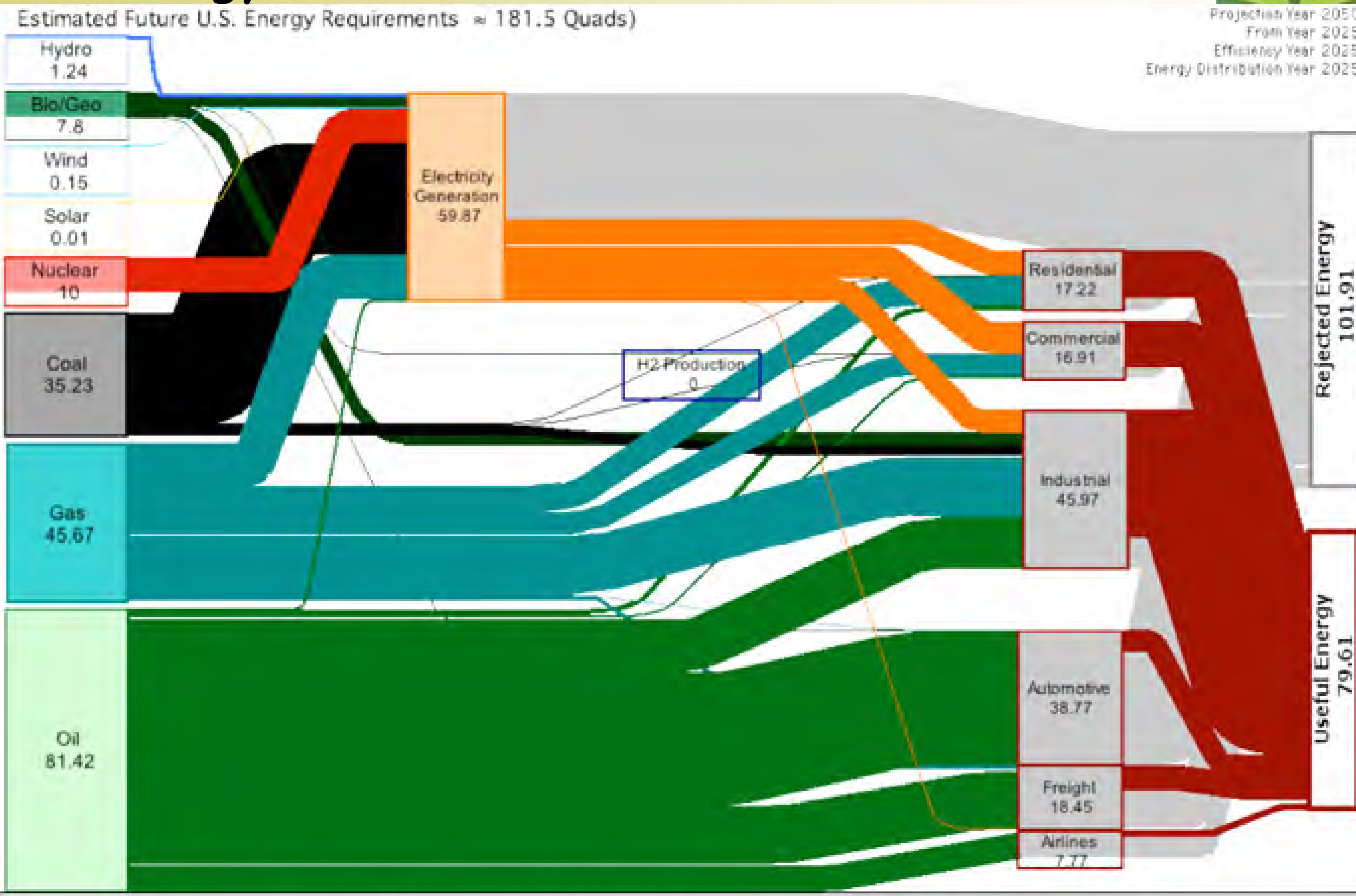
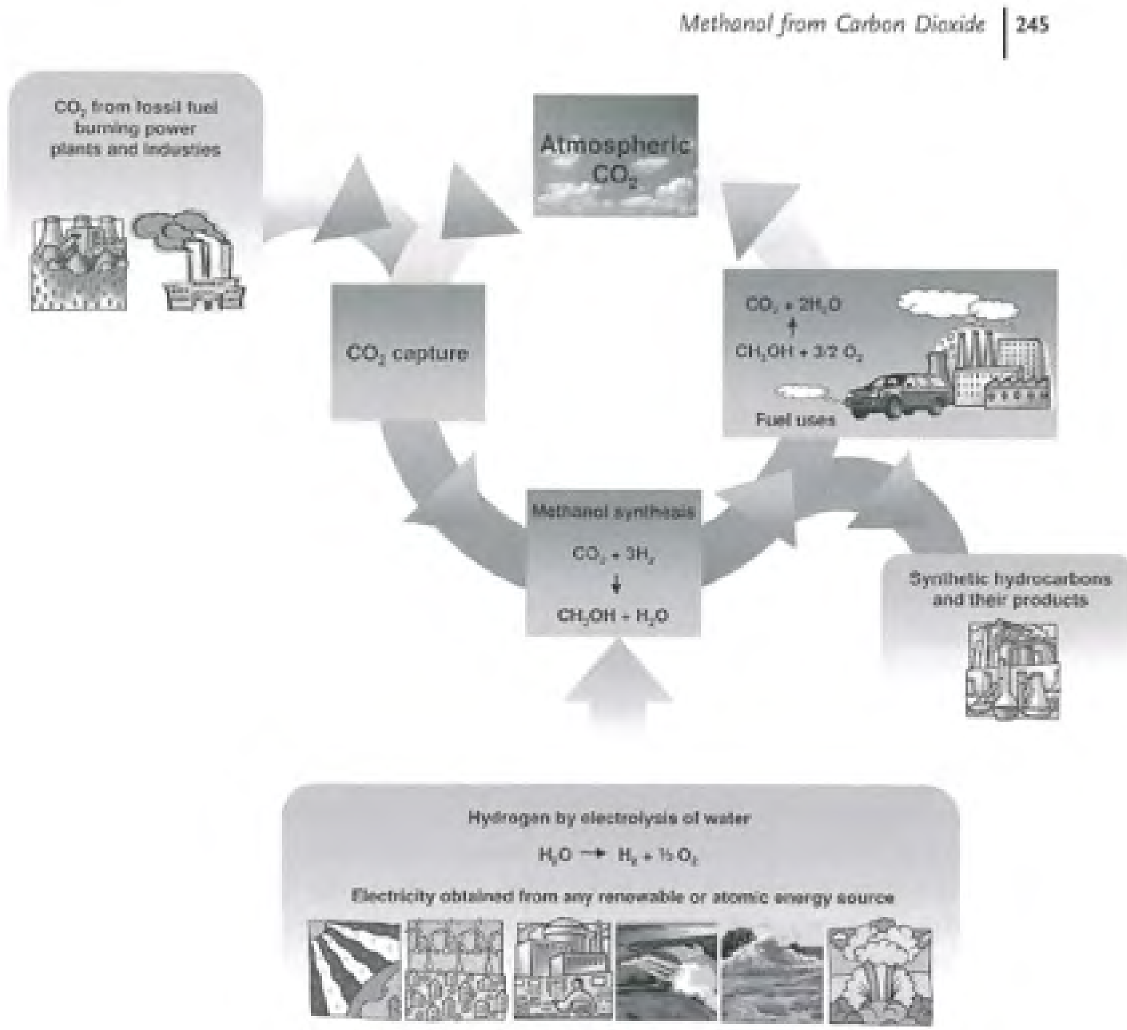
US Energy Flow 2050



Scenario 3. Linear extrapolation of *Annual Energy Outlook* projections for 2020-2025 out to 2050. A driving age population of 318 million, averaging 19,500 miles driven per year in 20 mpg vehicles, requires 39 Quads of petroleum or 18 million bbl/day.

From Beyond Oil and Gas: The Methanol Economy
by Olah, Goeppert, and Prakash



Ultimate Goal – Atmospheric CCS + Carbon Free Energy → "Carbon Neutral" Transportation Fuel

Renewable Liquid Fuels

Three steps from electricity to fuel

1. Electrolysis for H_2 generation → 70% efficient
2. CO_2 capture → Our focus: Efficient, high-rate direct-air CO_2 capture has never been demonstrated
3. Reaction of CO_2 and H_2 to fuel → 70% efficient

PARC Innovation for CO_2 capture

- Spray tower capture + electrochemical-based CO_2 recovery

Potentially very energy efficient

PARC invention: high-pressure electrodialysis

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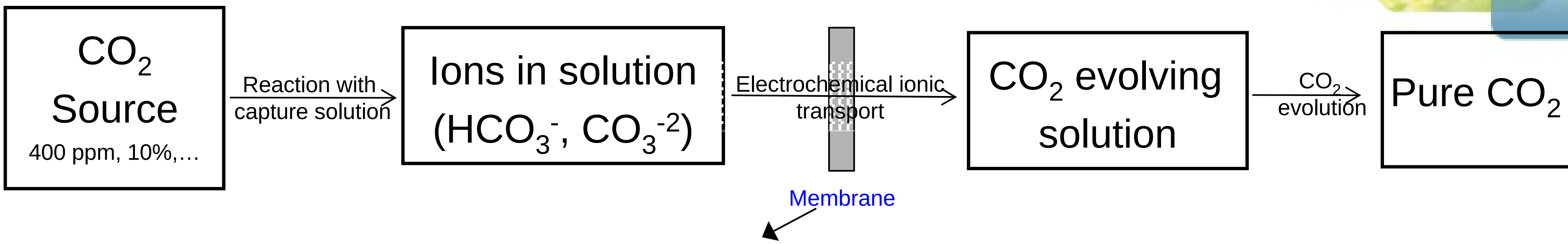
Renewable Liquid Fuels

Common mechanism to electrochemical methods



Bipolar Membrane Electrodialysis (BPMED)

Well-established commercial technology for separating a salt into acids and bases without the addition of other chemicals

All commercial examples deal with liquid phase solutions because gas bubbles in the membranes lead to localized high current density and membrane damage

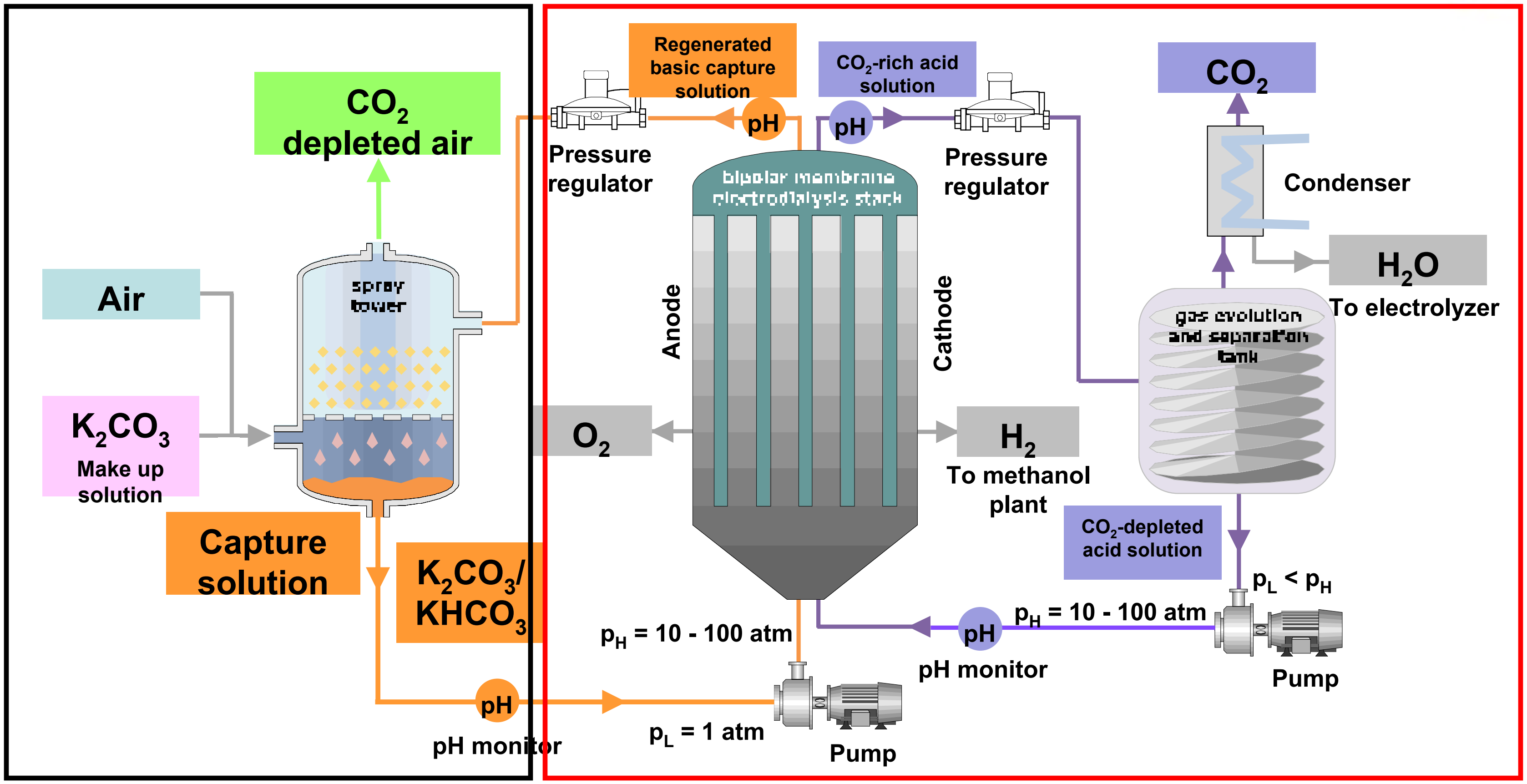
PARC innovations

Metric	Relation to system parameters	PARC Innovation[1]	PARC proposal	Existing Technology
Energy consumed per CO_2	$\propto pH_{acid} - pH_{base}$	**pH control via flow rate**	$pH_{acid} - pH_{base} \leq 7$	$pH_{acid} - pH_{base} = 14$
Membrane area, System size	$\propto$ **Current density**	**High pressure**	**100 mA/cm^2**	**$\leq$ 10 mA/cm^2**
Reliability	**In-stack CO_2 evolution decreases reliability**	**High pressure**	**10 – 100 atm**	**1 atm**

- Energy efficiency improved by at least a factor of two
- Membrane area and size decreased by a factor of ten
- First reliable gas-evolving electrodialysis system

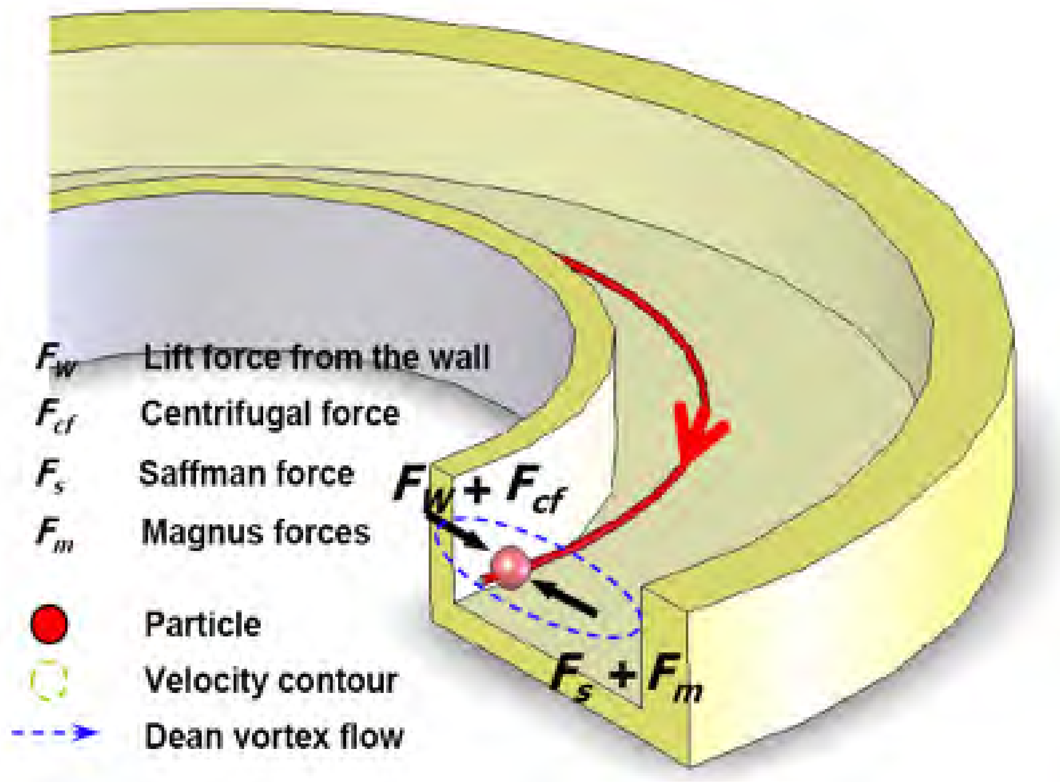
Renewable Liquid Fuels
(DARPA Funded)

PARC



Karl Littau, "System and method for recovery of CO_2 by aqueous carbonate flue gas capture and high efficiency bipolar membrane electrodialysis," U.S. Patent Pending.

Water Filtration: Hydrodynamic force balance to separate neutrally buoyant particles

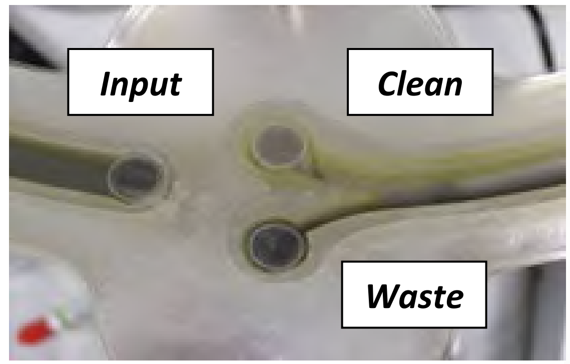


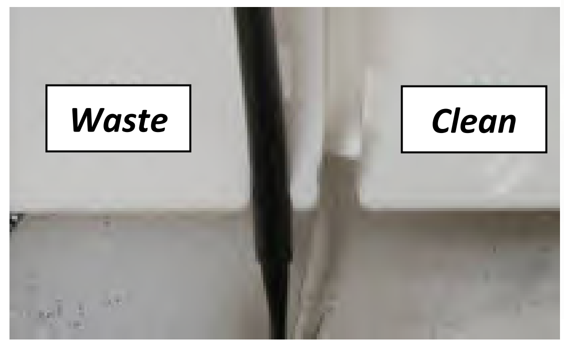
Note: control of 4 forces allows design for specific separations by mass or size

Hydrodynamic Separator
(ONR & DARPA Funded for Desalination)

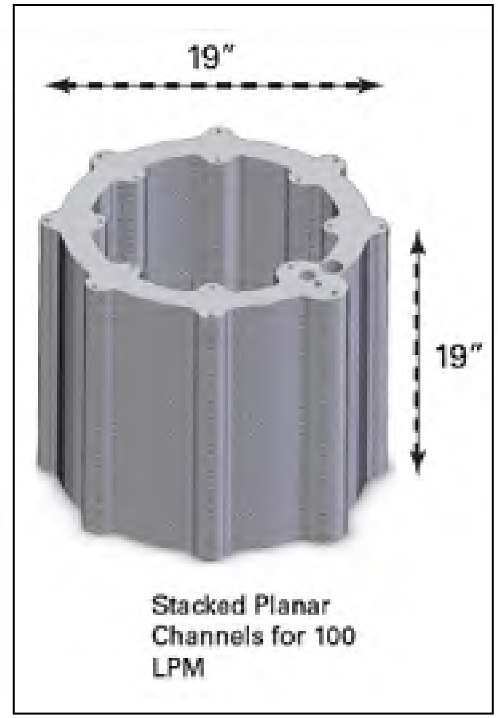
10 LPM hand-tooled demo
100 LPM demonstrated w/parallel units

Also demonstrated gravity fed separation, pressure of 2psi ~4 ft elevation



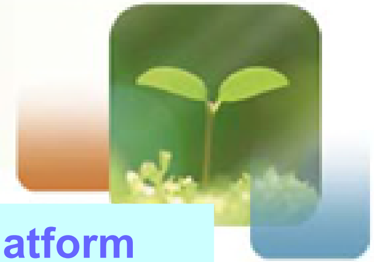


After one turn, particles move to one side and can be separated into two streams



Modular 100LPM design

Numerous samples tested in lab for different target applications



Generic capability: platform technology for separation of particles from a moving fluid

Water Applications

Pre-treatment for RO
- e.g. seawater from 3 distinctly different sites

Industrial water purification
- e.g. CMP slurry reclaim, ….

Waste water remediation
- Separation of sludge & precipitated divalent metal ions

Power plant cooling tower
- Separate precipitated scalants

Municipal Water treatment
- Efficient chemical usage and replacement of sedimentation

Petroleum refining
- Separation of immiscible fluids

Produced waters
- Separate oil and divalent metals to recycle water

Agricultural water

Other Application Areas

Bio medical
- Plasma separation and sample prep for lab-on-chip devices

Auto & jet fuel refinement
- Particle (grit) removal

Chemical (colloid) industry
- Particle screening and fractionation

Food & Beverage Industry
- Pathogen screening, water purification, recycling

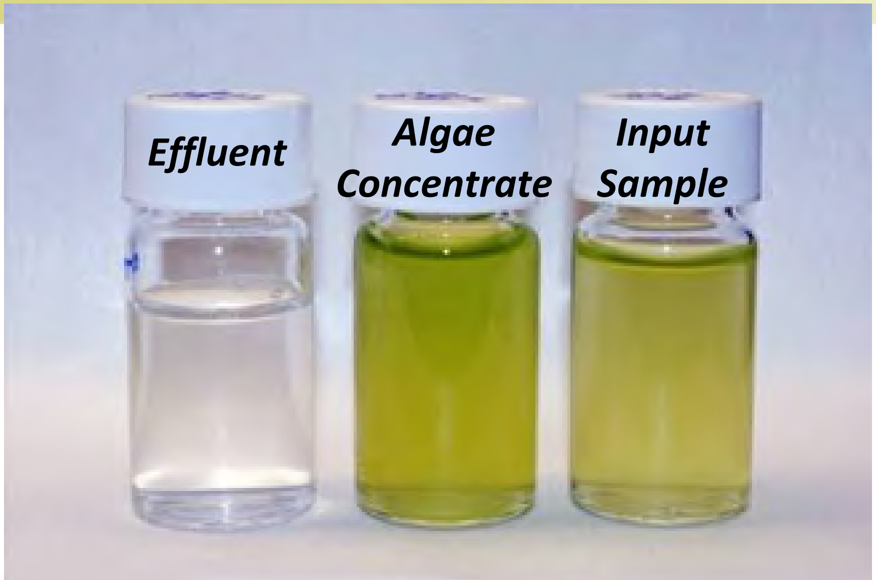
Mineral processing

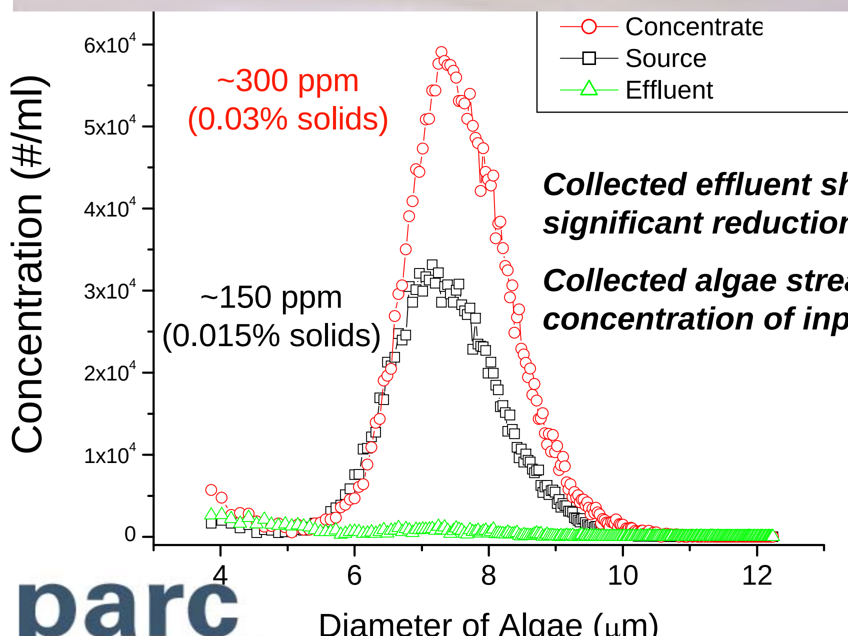
High Throughout Screening (HTS) for waterborne pathogens
- Increase sensitivity and selectivity for downstream detectors

Algae Dewatering for bio fuels
- Increase harvest

Separation of Algae

(Current DOE Proposal)

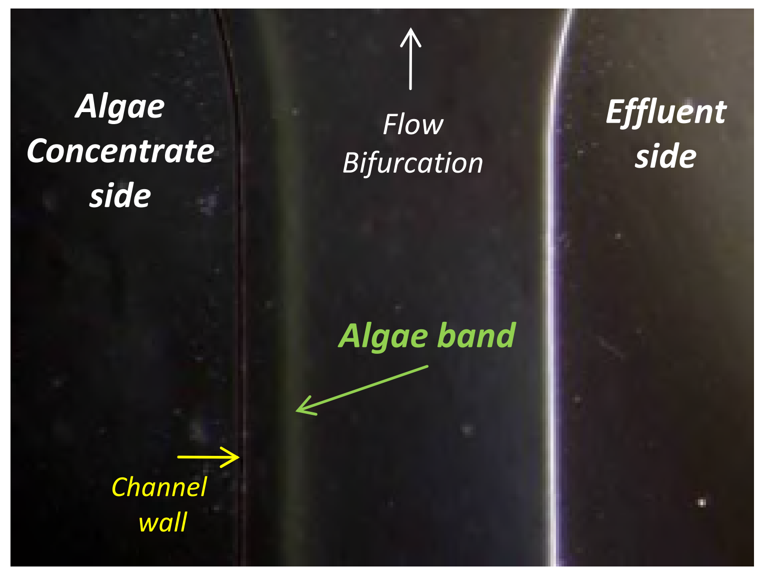




Collected effluent shows significant reduction in algae

Collected algae stream has 2X concentration of input sample

Observed size is in 5-10 um range with some larger aggregates



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Software Projects and Concepts in Adaptive Energy

Markus Fromherz / Teresa Lunt

Directors,
Intelligent Systems Laboratory /
Computing Science Laboratory

July 2009

Computing Science Laboratory

Ubiquitous Computing: *Anticipate user needs*

Physical Context → Electronic Context → Preference Model → Behavior Model

↓

User Intention Model

↓

Info Retrieval | Advertising | Group coordination | Health monitoring

Printing & Imaging

- **Xerox Modular Controller**
  - Architecture for printer system "core"
  - High speed parallel imaging for full color variable data printing

Ethnography

- User-centered opportunity discovery
- Product and service concept development

In-depth in-situ interaction analysis:

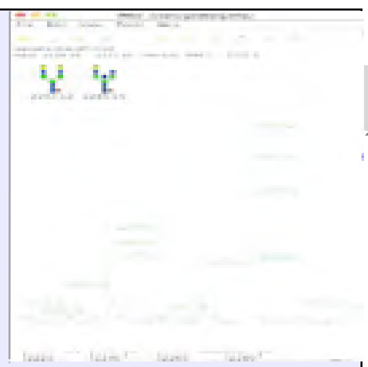
- Customer relationship, service, & sales
- Knowledge sharing
- Natural human-machine interaction

Ad Hoc Networking

- **Content-Centric Networking**
  - Seamless & efficient **internetworking** across user applications, information media, and resources in the environment
- **Context-Aware Protocol Engine**
  - High-throughput multihop **wireless** context-aware protocols deliver orders of magnitude performance improvement over WiFi

Bioinformatics software

- ByOnic deciphers mass spectrum of unknown peptides
- ComByne detects proteins by combining info from peptides
- Cartoonist identifies *glycans* (complex protein modifications)



Security & Privacy

Robust, usable solutions for ***Data Loss Prevention, Mobile Security and Cloud Computing***

Intelligent Systems Laboratory

Partners:
BAE Systems, Boeing, Lockheed Martin, SAIC, SRI, universities, …

Competencies

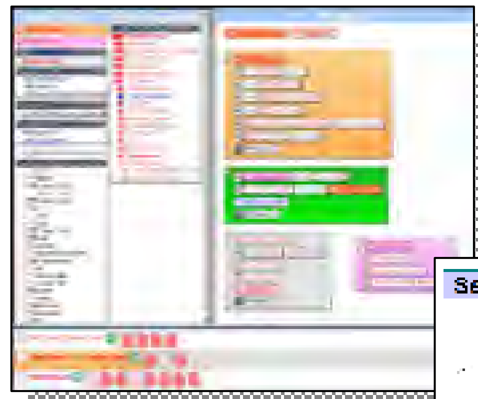
Interactive and Embedded Computing

Model-based reasoning
Natural language and image processing
Social and collaborative computing
Large-scale data mining, machine learning, cloud computing
Modeling: cognition, tasks, social, machines
User studies, human-centric automation, intelligent interfaces

Applications

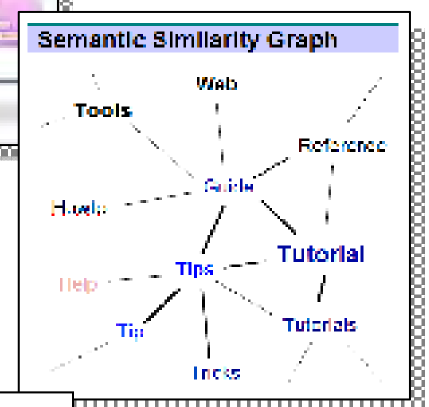
People

Intelligent knowledge workspaces
Knowledge sharing, collective intelligence
Business process automation



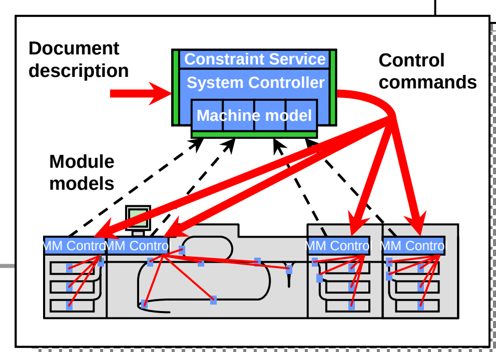
Information

Knowledge extraction, search, question answering
Image analysis, classification, search
Semantic content and context networks
Information visualization, dashboards, sensemaking



Machines

Intelligent planning and control
Modular industrial automation
Mobile robotics (aerial, fleets)
Adaptive energy optimization



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Adaptive Energy Portfolio

Competencies

…applied to intelligent control & energy efficiency opportunities

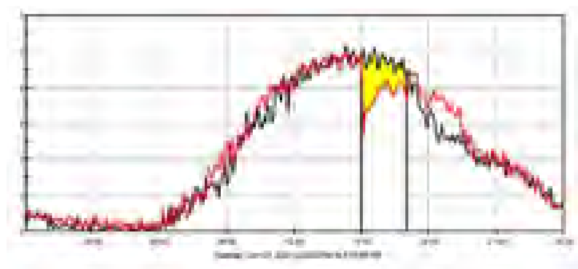
Planning/optimization/control
Data analysis/mining
Human-centric automation & intelligent interfaces

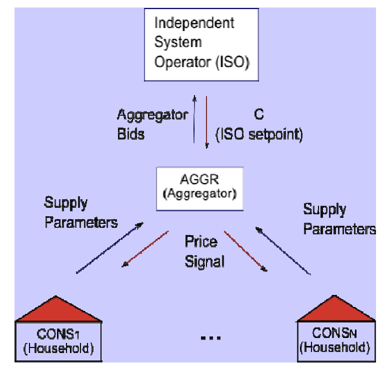
Hardware systems (sensing and actuation)
Communications, networking, and security
Machine learning

Applications

Intelligent Control

Fast Demand Response
Self-Healing Smart Grid
Dynamic Optimization of Energy Storage
Vehicle Power Management





Energy Efficiency

Data Center Optimization
Collaborative Homes
Adaptive Lighting

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Fast Demand Response

…applied to intelligent control & energy efficiency opportunities

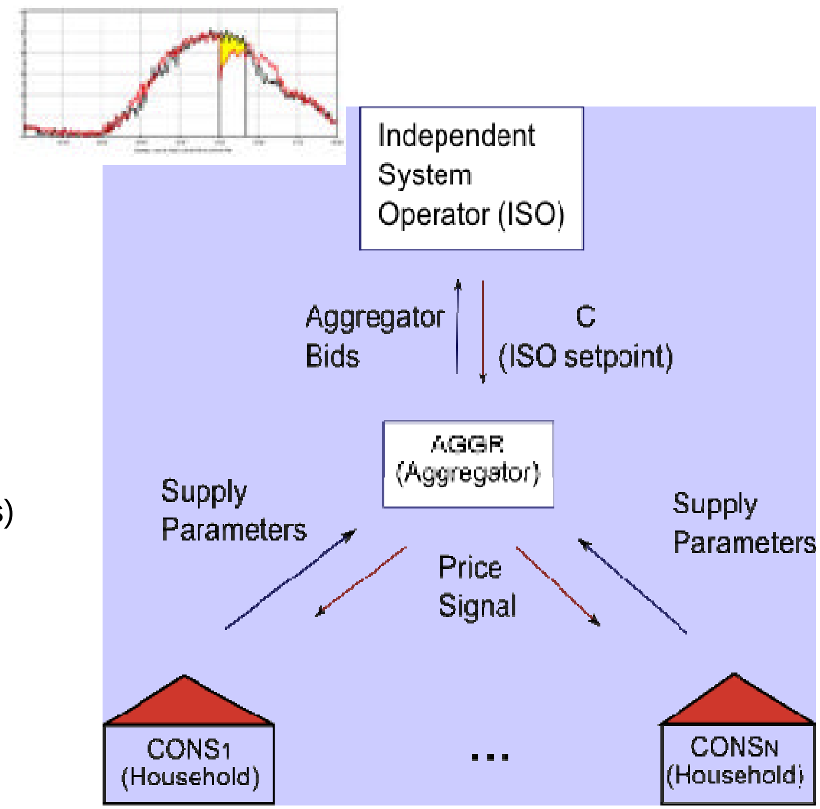
Competencies

Planning/optimization/control
Data analysis/mining
Human-centric automation & intelligent interfaces

Hardware systems (sensing and actuation)
Communications, networking, and security
Machine learning

Applications

- Problem:
  - Inefficient "peaker plants" currently provide expensive ancillary services
  - Power generation is less predictable with renewables, exacerbating the problem of balancing generation vs. demand
- Solution:
  - Aggregate and shed/shift large numbers of smaller demand-side loads to replace highest value ancillary services (e.g., regulation, spinning reserves)
- Differentiation:
  - Rapid ramp up of demand reduction (seconds vs. minutes)
  - Optimization of consumer & load "utility" with economic incentives
  - Automation of consumer/load participation
- Applications:
  - Aggregator (or utility) DR services
  - Consumer, micro-grid energy management



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Collaborative Homes — Modeling "Utility"

Competencies

…applied to intelligent control & energy efficiency opportunities

Planning/optimization/control
Data analysis/mining
Human-centric automation & intelligent interfaces
Hardware systems (sensing and actuation)
Communications, networking, and security
Machine learning

Applications

- Problem:
  - Consumer energy management systems can respond to price signal or programming, but have yet to act as proxies for people relative to their value of energy services
- Solution:
  - Utility model for residential consumers that automates preference elicitation based on ethnographic studies of user environments
- Differentiation:
  - Preference elicitation model based on observed behavior, that learns from historical user actions
- Applications:
  - Consumer energy management solutions
  - Intelligent energy services

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Self-Healing Smart Grid

Competencies

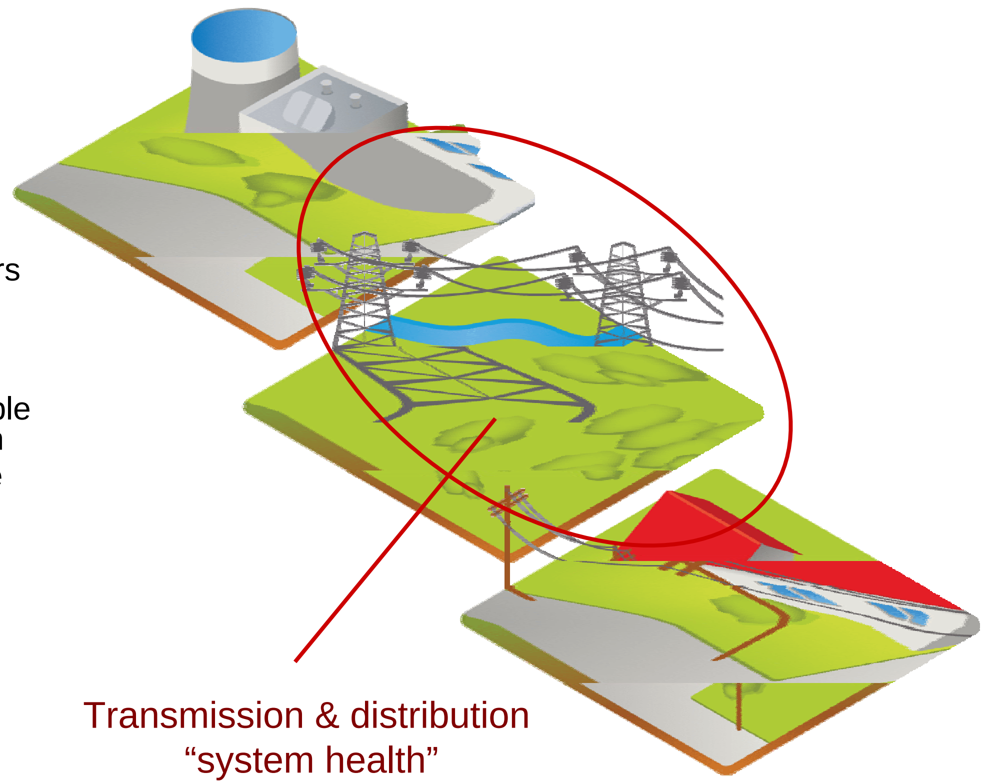
…applied to intelligent control & energy efficiency opportunities

Planning/optimization/control
Data analysis/mining
Human-centric automation & intelligent interfaces

Hardware systems (sensing and actuation)
Communications, networking, and security
Machine learning

Applications

- Problem:
  - Interconnection and decentralization of energy resources will make it more difficult to detect, isolate, and repair failures to ensure reliability & security
  - Data generated from Phase Measurement Units and other sensors will overwhelm system operators
- Solution:
  - Real-time data & pattern analysis algorithms for fault detection; based on detailed models of credible failures from physics-based modeling & simulation
  - Distributed architecture for self-healing in the wide area management system
- Differentiation:
  - Prognostics for impending failures
- Applications:
  - Transmission
  - Distribution



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Dynamic Optimization of Energy Storage

Competencies

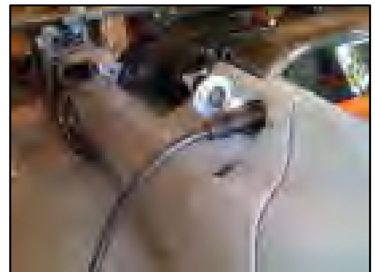
…applied to intelligent control & energy efficiency opportunities

Planning/optimization/control
Data analysis/mining
Human-centric automation & intelligent interfaces

Hardware systems (sensing and actuation)
Communications, networking, and security
Machine learning

Applications

- Problem:
  - Emerging energy storage from electric vehicles will provide multiple, sometimes competing uses for the same batteries
  - Battery control systems don't consider the "health" of batteries relative to use
- Solution:
  - Develop a parametric model of Li-ion cell aging based on operational stressors & environmental conditions
  - Develop a battery management control architecture to optimize health relative to economic parameters
- Differentiation:
  - Prognostics for batteries used in both automotive and grid modes
- Applications:
  - Automotive battery control systems
  - Grid-attached storage systems



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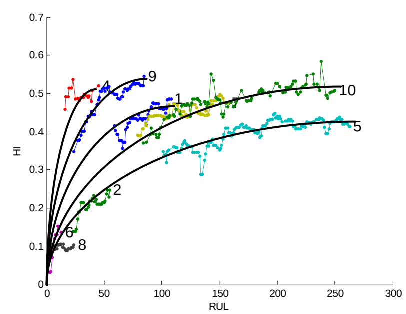

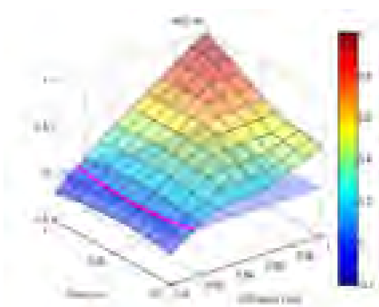

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Vehicle Power Management

…applied to intelligent control & energy efficiency opportunities

Competencies

Planning/optimization/control
Data analysis/mining
Human-centric automation & intelligent interfaces

Hardware systems (sensing and actuation)
Communications, networking, and security
Machine learning

Applications

- Problem:
  - Vehicles have real constraints (weight, range, etc.) in optimizing energy use
- Solution:
  - Power systems design optimization based on stochastic information on future costs, mission profiles, and operating environment
- Differentiation:
  - Power generation and consumption information for relevant power sources and loads
  - Mission (usage) profiles and other relevant constraints
- Applications:
  - Vehicle power systems design
  - Storage provisioning for the grid

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Data Center Optimization

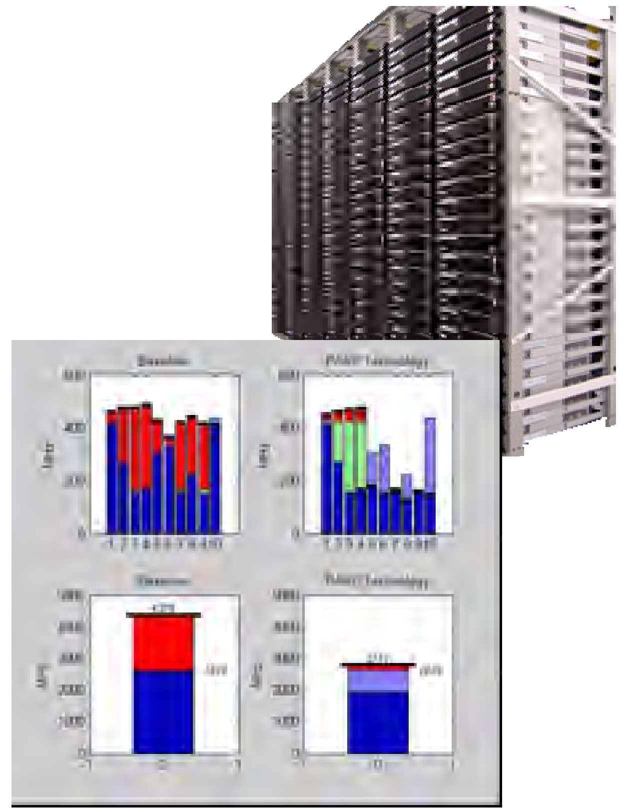
Competencies

…applied to intelligent control & energy efficiency opportunities

Planning/optimization/control
Data analysis/mining
Human-centric automation & intelligent interfaces
Hardware systems (sensing and actuation)
Communications, networking, and security
Machine learning

Applications

- Problem:
  - Data Centers consume ~3% of U.S. energy supply; demand to quadruple by 2020; carbon emissions to surpass airlines within 5 years
  - Overprovisioning is addressed by virtualization, but that doesn't consider service level requirements for heterogeneous jobs
- Solution:
  - Model-based optimization of resource allocation in virtualized environment to decrease powered servers ("always available" vs. "always on")
- Differentiation:
  - Power consumption information for relevant data center loads (virtual machines)
  - Service Level Agreements and other relevant constraints
- Applications:
  - Data centers/server farms energy management



Adaptive Lighting

Competencies

…applied to intelligent control & energy efficiency opportunities

Planning/optimization/control
Data analysis/mining
Human-centric automation & intelligent interfaces

Hardware systems (sensing and actuation)
Communications, networking, and security
Machine learning

Applications

- Problem:
  - Outdoor lighting is always-on, using more than 15 TWh/yr. LED lighting promises energy efficiency, but lacks technology to enable applications for further energy savings
- Solution:
  - Utilize a combination of powerline, wireless, local sensing, and light modulation networking protocols to convert lighting into an active network
- Differentiation:
  - Enables energy-saving applications without an external network topology: commissioning, dimming, monitoring, etc.
- Applications:
  - Outdoor street lights
  - Building energy management, security

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Adaptive Energy Portfolio

Competencies

…applied to intelligent control & energy efficiency opportunities

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Applications

Intelligent Control

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Self-Healing Smart Grid
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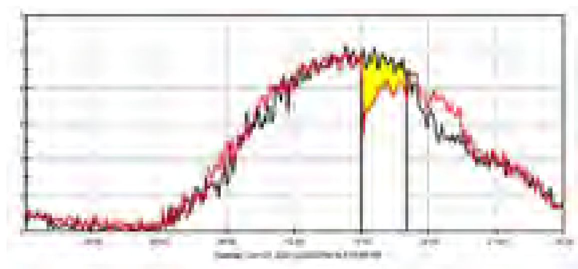
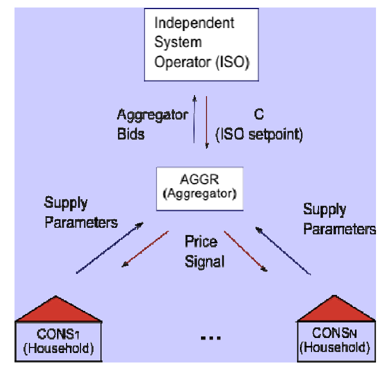
Vehicle Power Management





Energy Efficiency

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