

# Virginia Tech's Sustainable Nanotechnology Program

Peter J. Vikesland

Department of Civil and  
Environmental Engineering



# We live in a world beset by complex problems



www.nytimes.com

## Obesity



www.multiculturalhealth.org

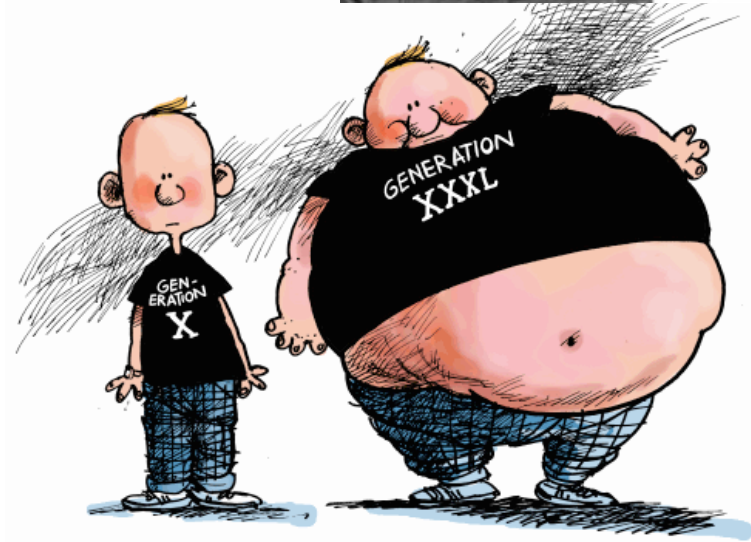
fabtoons @ felvs.net  
caglecartoons.com



www.newscientist.com



www.nationalreview.com



CHILDHOOD OBESITY EPIDEMIC..

## Climate Change

# We live in a world beset by complex problems

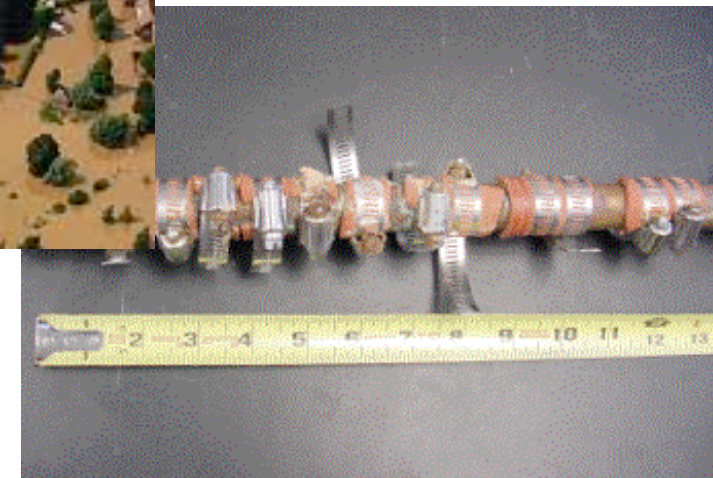
**Agriculture 92%**

Industry 4.4%

Domestic consumption 3.6%



# Water



Source: Marc Edwards, VT

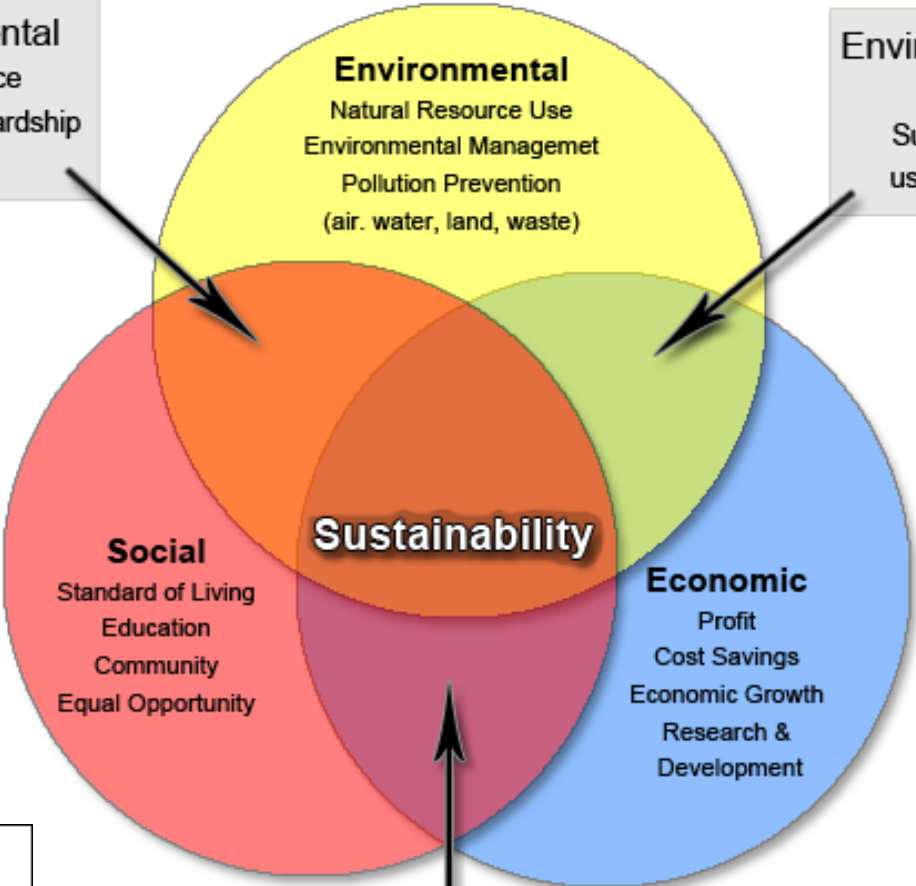
We live in a world beset  
by complex problems

Energy

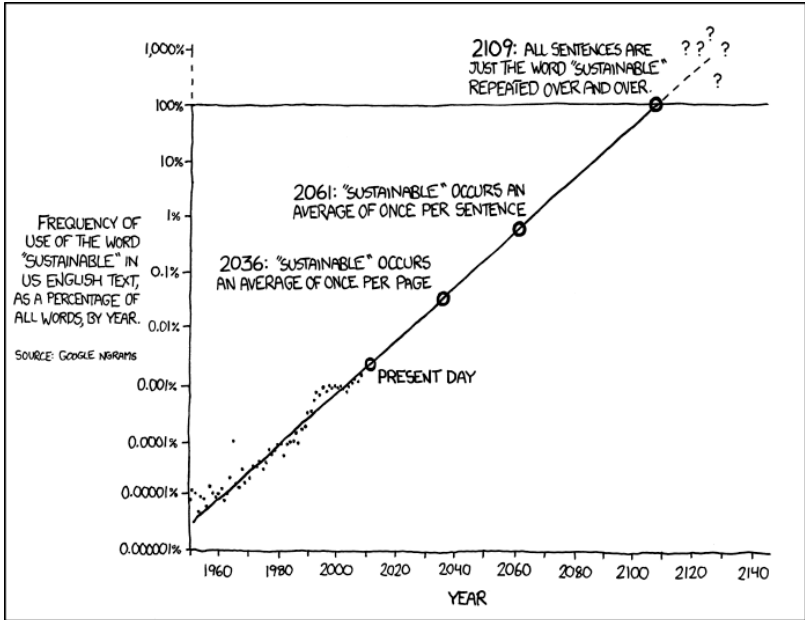


**Social-Environmental**  
 Environmental Justice  
 Natural Resources Stewardship  
 Locally & Globally

**Environmental-Economic**  
 Energy Efficiency  
 Subsidies / Incentives for  
 use of Natural Resources

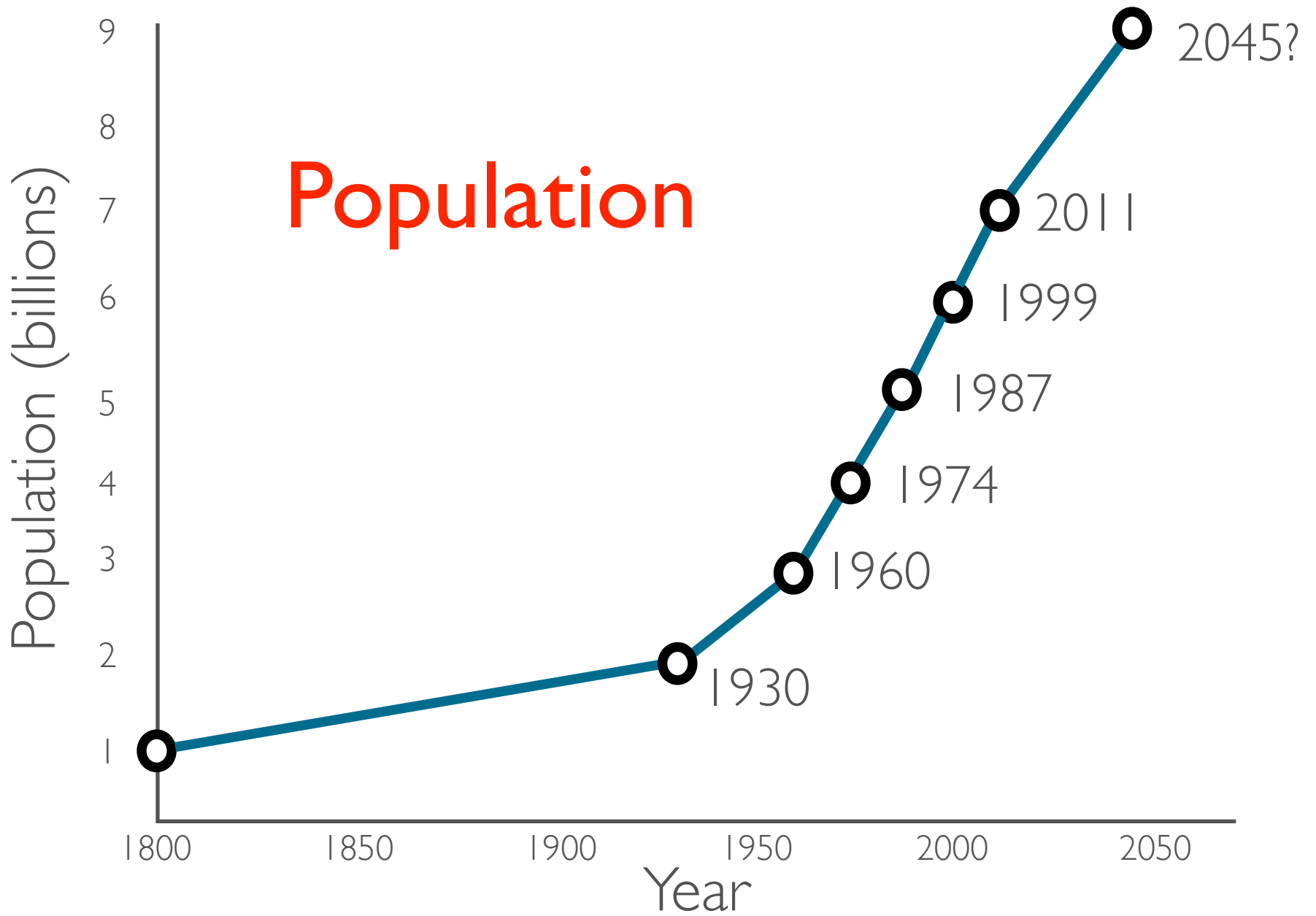


**Economic-Social**  
 Business Ethics  
 Fair Trade  
 Worker's Rights



THE WORD "SUSTAINABLE" IS UNSUSTAINABLE.

# Sustainability



# Consistencies amongst these problems

- 1) Difficult problem formulation
- 2) Multiple but incompatible solutions
- 3) Open ended time frames
- 4) Novelty
- 5) Competing value systems or objectives

**To address these challenges  
requires new approaches...**

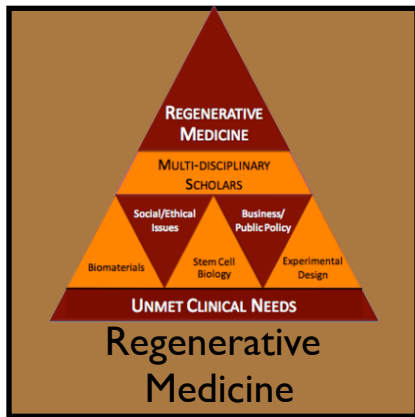
“...the biggest problems we need to solve now require the expertise of people from different backgrounds who bridge the gap between disciplines. Unless we learn to share our ideas with others, we will be stuck with a word of seemingly impossible problems”



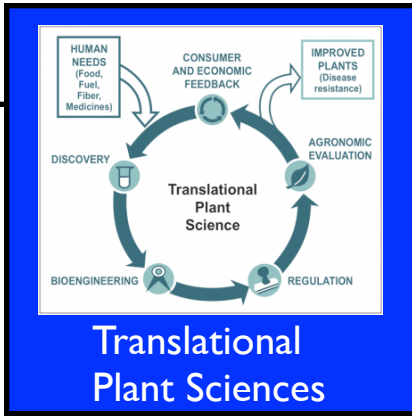


# Interdisciplinary Graduate Education Programs (IGEPs) at Virginia Tech

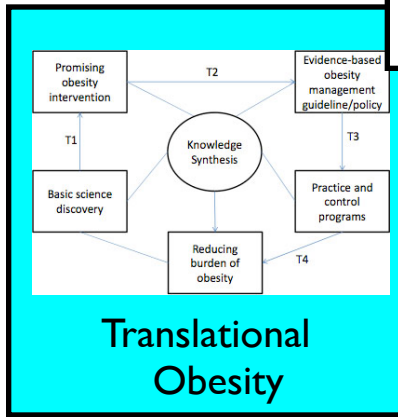
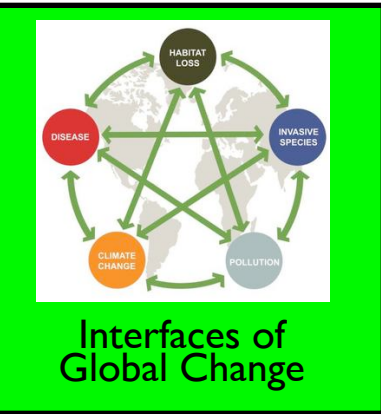




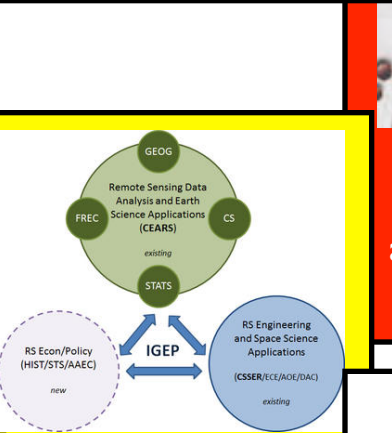
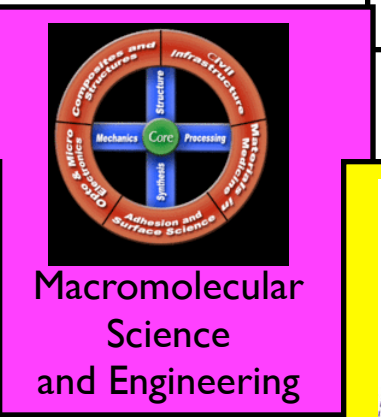
Multi-Scale Transport in Environmental and Physiological Systems



Water INTERface



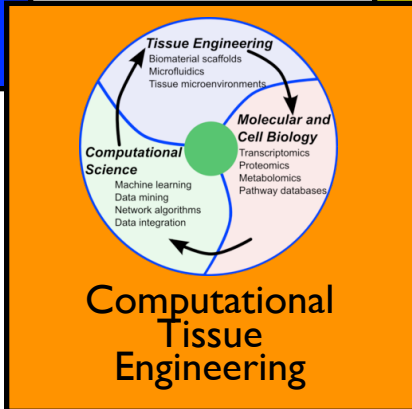
BioBuild  
Bio-Inspired Buildings



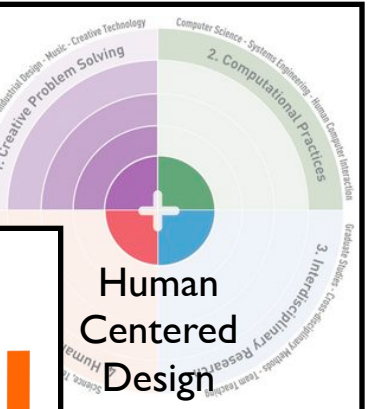
GBCB  
Interdisciplinary Ph.D. Program  
Genetics, Bioinformatics, and Computational Biology



Disaster Risk Management

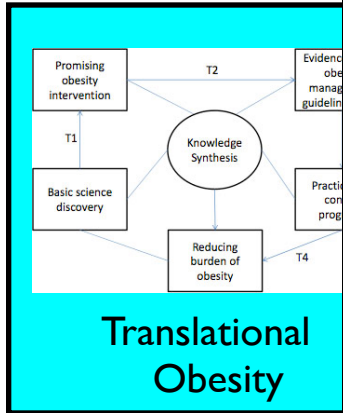
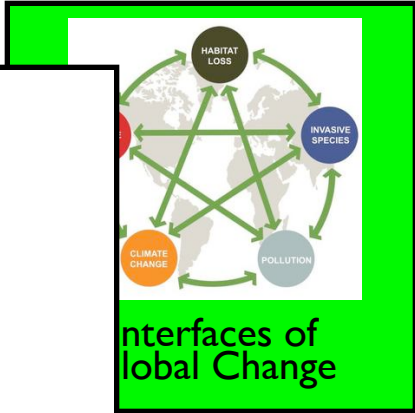
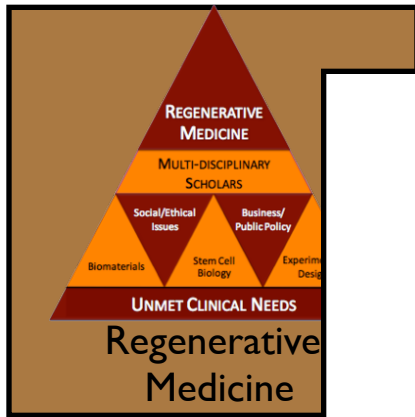


Remote Sensing



VT  
SUN  
Sustainable Nanotechnology

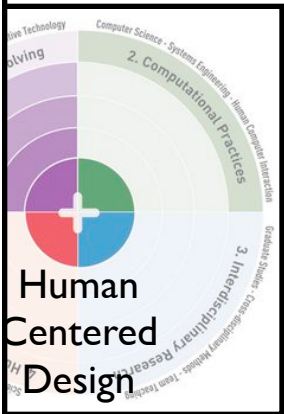
# IGEPs at Virginia Tech



**GBCB**  
 Interdisciplinary Ph.D. Program  
**Genetics, Informatics, Computational Biology**



**Disaster Risk Management**



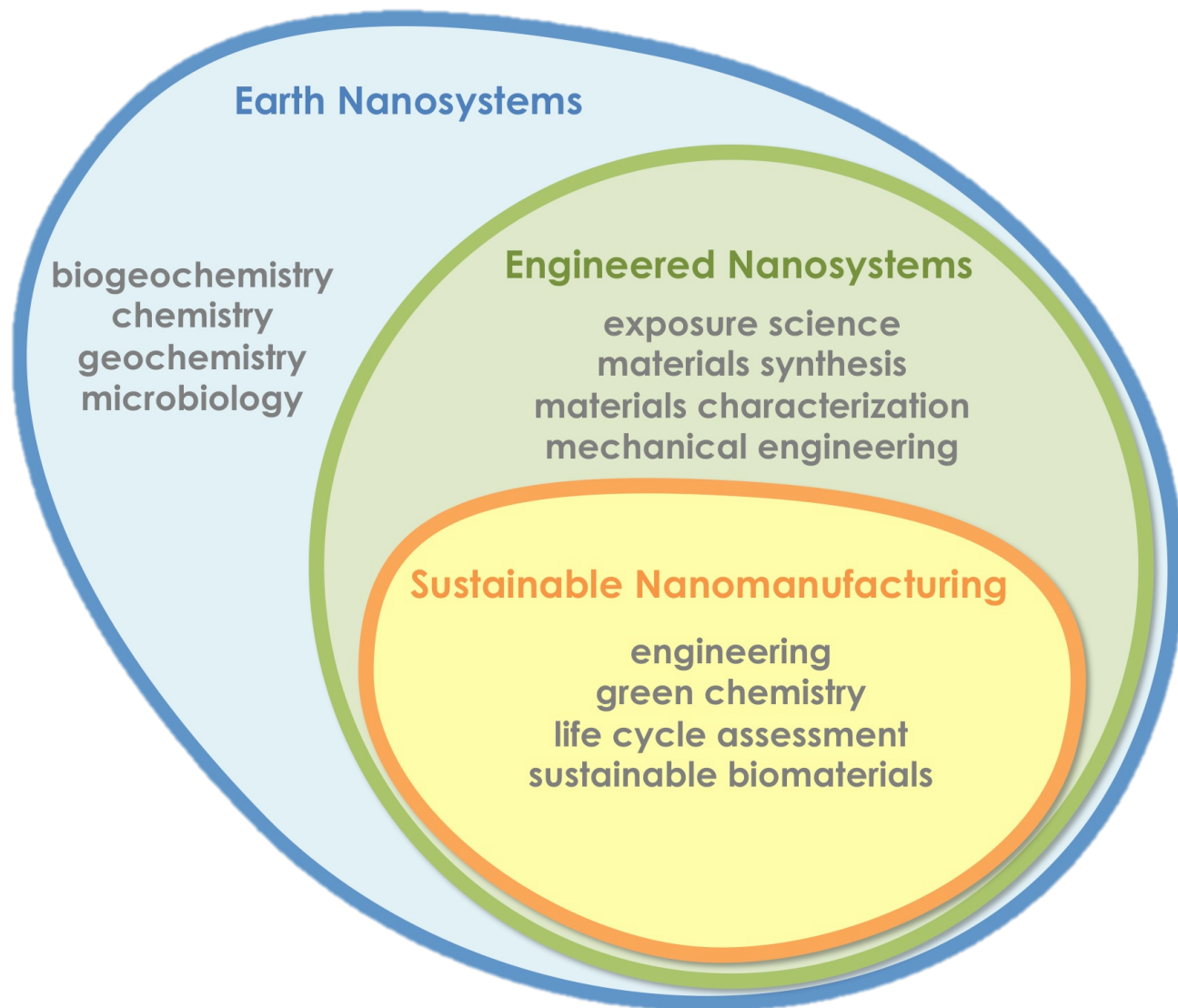
# VT SUN

## Sustainable Nanotechnology

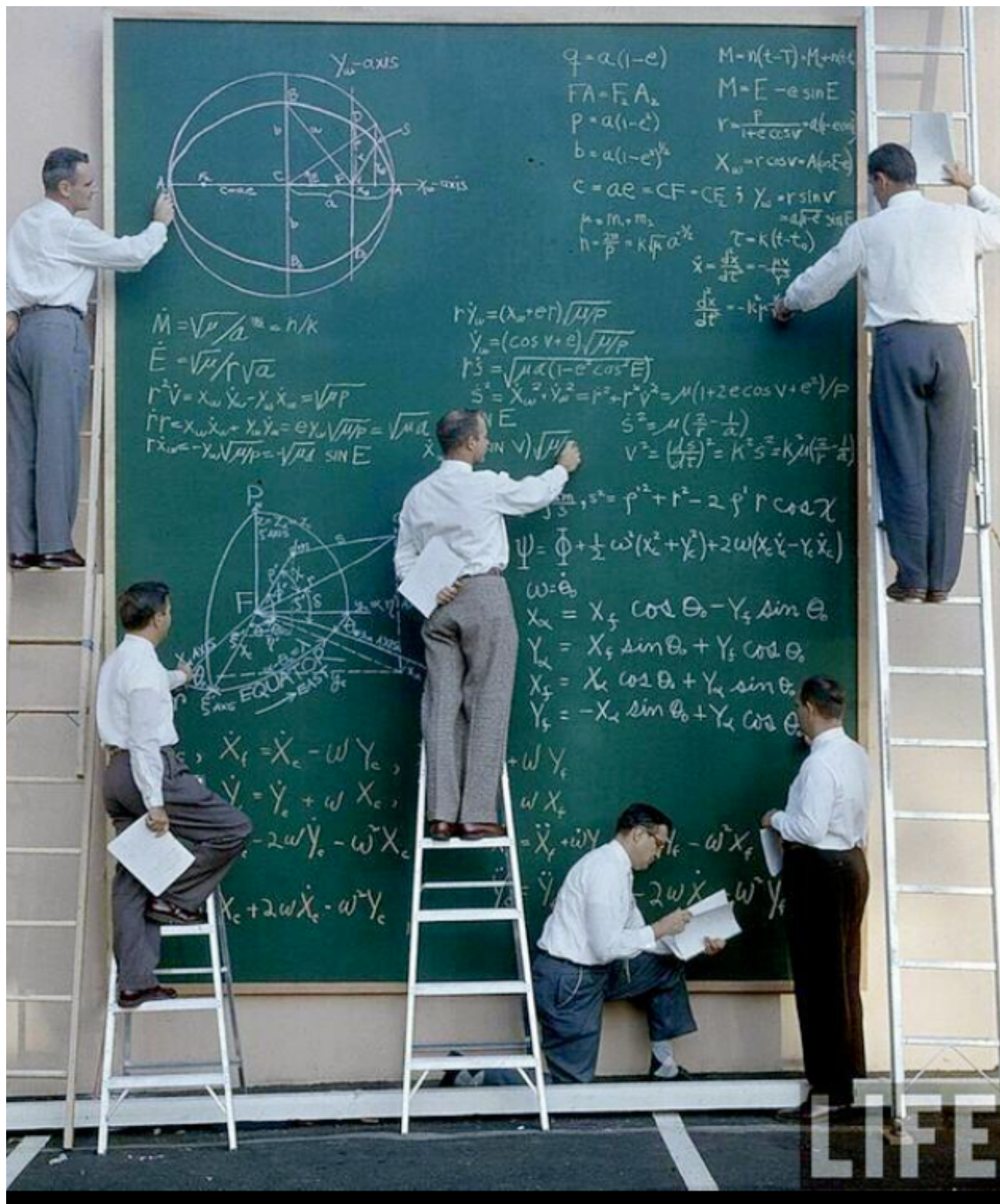
Sustainable Nanotechnology

IGEPs at Virginia Tech

*VT SuN supports scholarly applications of nanoscale science and engineering to improve our understanding of nanoparticle interactions within the environment as well as to enhance our ability to apply nanotechnology to solve global environmental challenges.*



Teams  
 have  
 always  
 been  
 required  
 to solve  
 complex  
 problems



Rocket Scientists  
 at NASA



Michael Hochella



F. Marc Michel

# Geosciences



Peter Vikesland

# Civil & Environmental Engineering



Linsey Marr



Amy Pruden



Nina Vance



Matt Hull

[ICTAS]



Lissett Bickford

# Biomedical Engineering & Mechanics

5 postdocs

15 graduate students

# Green Eng.



Sean McGinns



Mitsu Murayama

# Materials Science & Engineering



Maren Roman



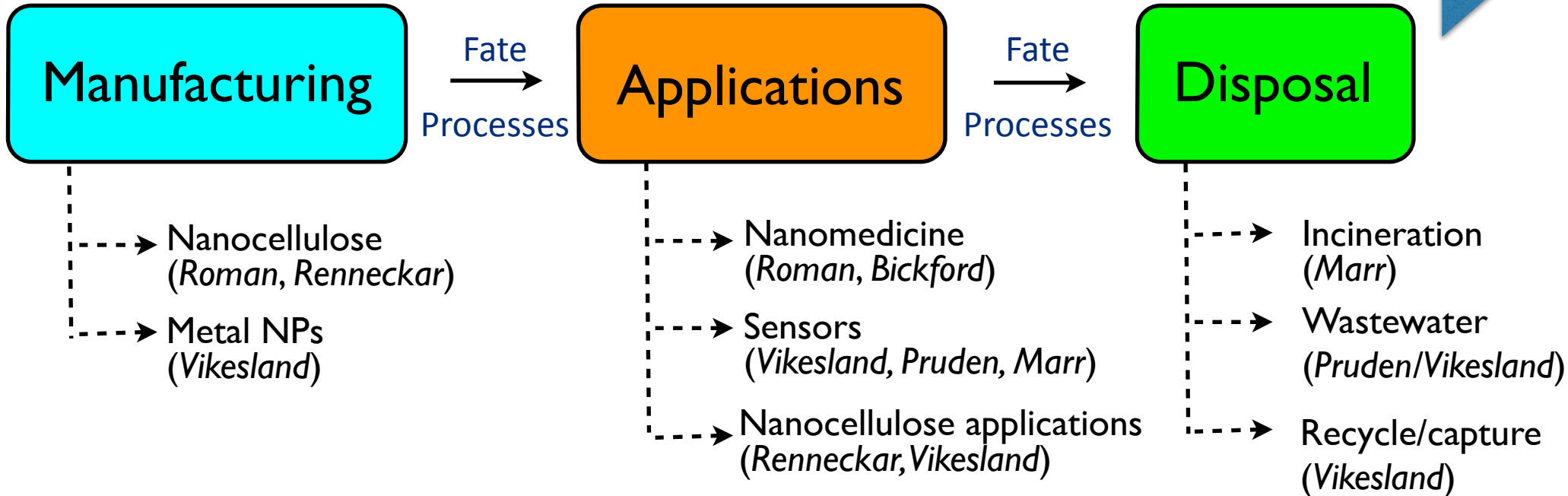
Scott Rennekar\*

# Sustainable Biomaterials



# Sustainable Nanotechnology

## Earth Nanosystems



### Fate Processes

$nC_{60}$  (Vikesland, Marr)       $CeO_2$  (Hochella, Marr)      Virus (Marr, Pruden)  
 Metals/Metal oxides/sulfides (Bickford, Hochella, Marr, Michel, Pruden, Vikesland)

### Life Cycle Assessment

AuNPs (McGinnis, Vikesland)       $CeO_2$   
 Nanocellulose (McGinnis, Renneckar)

“The reality of the creative process is that it often requires **persistence**, the ability to stare at a problem until it makes sense.”

In the field of sustainable nanotechnology education **persistence** encompasses a wide range of different approaches.





# THE PROGRAM

Three “Core” courses

Environmental Nanotechnology

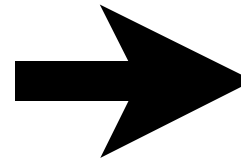
Interdisciplinary Sustainable Nanotechnology

Engineering Ethics

One “Elective” course

Weekly meetings

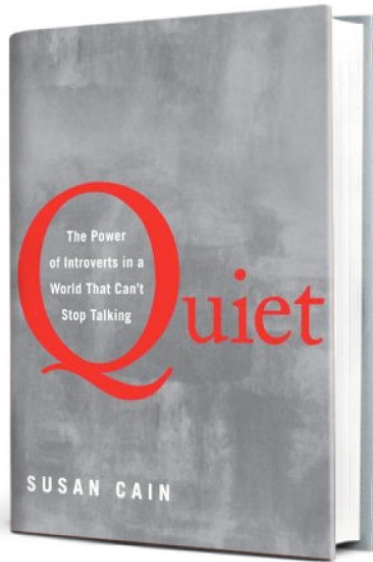
Co-advising of students



# GOAL

A cohort of students, faculty, and affiliates with the collective expertise to address the complexities of sustainable nanotechnology

# Classes: Learning to understand one another.



To increase energy, those who...

- turn to others are an E (extroversion).
- turn inward are an I (introversion).

Those who take in information in a...

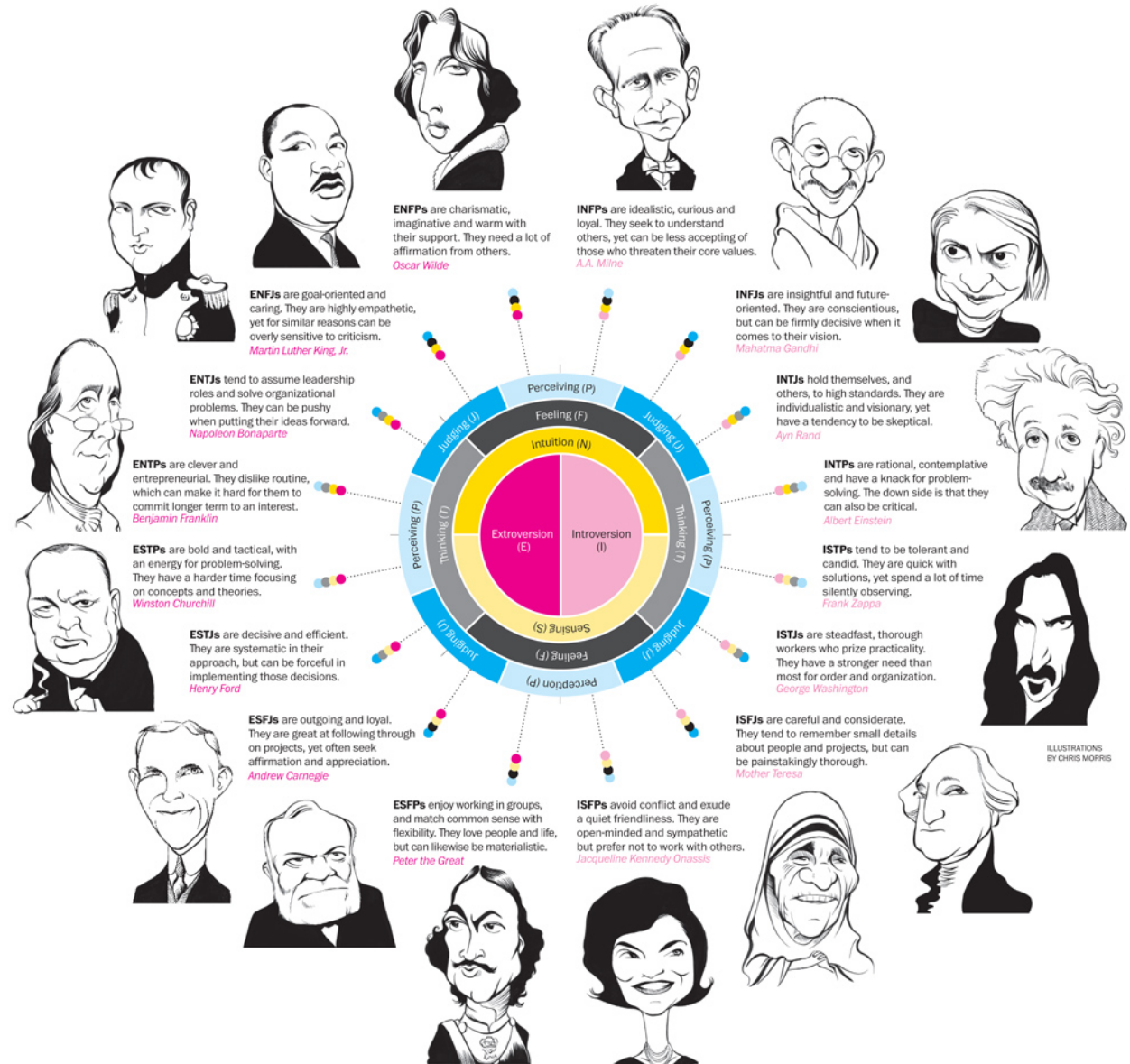
- creative way are an N (intuition).
- pragmatic way are an S (sensing).

When making decisions, those who...

- seek harmony are an F (feeling).
- seek objective truth are a T (thinking).

Those who prefer to...

- get closure and act are a J (judging).
- stay open and adapt are a P (perceiving).



ILLUSTRATIONS BY CHRIS MORRIS

# Meetings: Learning to speak to one another.



**Conferences:** Learning to share with colleagues.

**Sustainable  
Nanotechnology  
Organization Annual  
Meetings**



# Social Media: Learning to share with others.

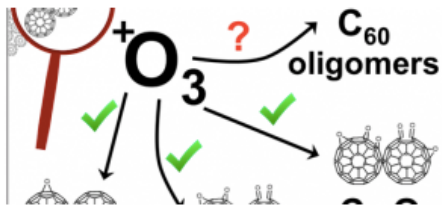


WHAT IS VTSUN? WHAT IS IGEP? ICTAS VIDEO TOUR VTSUN @ TEDx

> 8600 Views in less than one year!

HOME VTSUN WEBSITE ICTAS VTSUN IGEP VT GRADUATE SCHOOL APPLYING TO VIRGINIA TECH

## C60 fullerenes are oxidized by levels of ozone found in ambient air



(This is a post by VTSuN member, Andrea Tiwari. You can reach Andrea at [ajtiwari@vt.edu](mailto:ajtiwari@vt.edu)) As we know, carbon is the basis of life on Earth - we are all "carbon-based life forms." The carbon ...

[Continue reading →](#)

Posted on February 25, 2014 by [coffeemug](#) · [Leave a comment](#)

## Learning Interdisciplinary Research



For the last year, I have been a member of the Virginia Tech Center for Sustainable Nanotechnology — affectionately known as VTSuN. Check out our awesome website here and an explanatory blog post here. VTSuN is (also) an ... [Continue reading →](#)

Posted on February 5, 2014 by [Marjorie Willner](#) · [Leave a comment](#)

## My first research experience



## Your one stop source for nanotechnology consumer products



Search ...

CHECK OUT THE OTHER IGEPs AND ANOTHER SUSTAINABLE NANO BLOG!

- Virginia Tech Interdisciplinary Graduate Education Blog
- MultiSTEPS IGEP Blog
- Water INTERface IGEP Blog
- Translational Obesity Research IGEP Blog
- Another awesome Sustainable Nano blog

VTSUN'S AWESOME NANO-TWEETS

**Tweets** [Follow](#)

**Marjorie Willner** @Willner\_M 33m

#idrday2014 a mention of diversity. Nice surprise. @IDRSociety @marinaeq @kpdepauw [pic.twitter.com/oKpwUouKSQ](http://pic.twitter.com/oKpwUouKSQ)

↻ Retweeted by VTSuN

Shared Vision  
Setting Expectations



@VTSuN

> 400 followers

Other accounts:

@petervikesland

@linseymarr

@waterARGome

@marjoriwillner

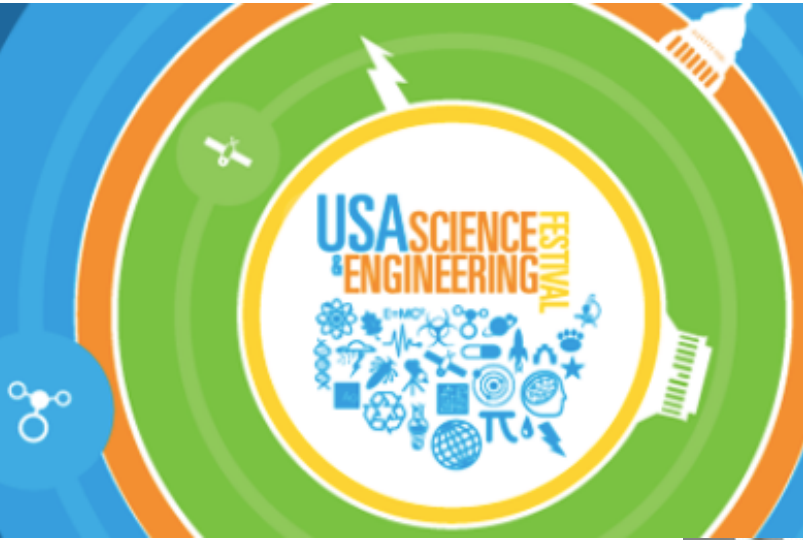
@marinavance

+ others

> 1200 followers

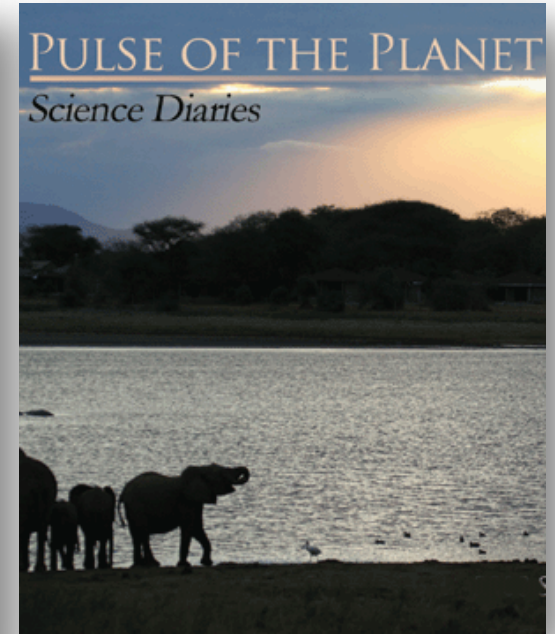
<https://blogs.lt.vt.edu/sustainablenano>

# Outreach: Learning to share with others.



Kids' Tech University

Outreach: Learning to share with others.



*Heard over 242 radio stations  
by 1.1M listeners per week,  
including Armed Forces Radio  
and the World Radio Network*

# Quantifying our successes



Rebecca French  
PhD 2011  
**AAAS  
Congressional  
Fellow**

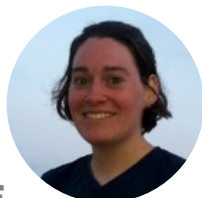


Andrew Whelton  
postdoc 2010  
**Assist Prof  
Purdue**



Bojeong Kim  
postdoc 2013  
**Assist Prof  
Temple**

Rebecca Lahr  
PhD 2013



**Assist Prof  
Michigan State**

## Graduated 13 PhDs

3 EPA STAR Fellows

5 NSF Student Fellows

8 ACS Student Awards

3 ICTAS Fellows

Nina Vance  
PhD 2012



**VTSuN  
Associate  
Director**



Manuel Monge  
postdoc 2013  
**Assist Prof**

**Univ Santiago  
Chile**



Jose Cerrato  
PhD 2010  
**Assist Prof  
U of New  
Mexico**

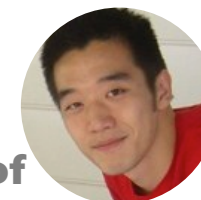


Matt Hull  
PhD 2011  
**ICTAS  
Program Manager**

Yanjun Ma  
PhD 2014  
**Assist Prof  
China Univ  
Mining & Technology**



Takuya Echigo  
postdoc 2010  
**Assist Prof**



**Shiga Univ, Japan**



# Press Coverage



CBCnews



Chicago  
Tribune

theguardian

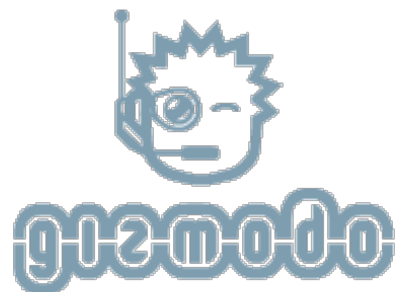
C&EN

SCIENTIFIC  
AMERICAN

THE ROANOKE TIMES

radio  
JOURNAL

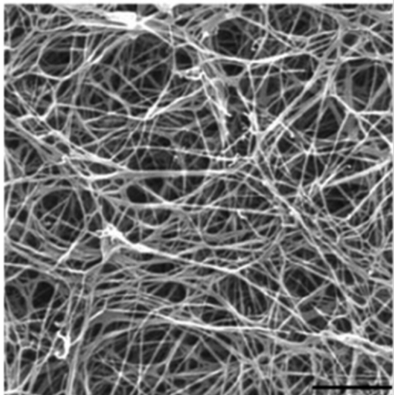
RUNNER'S WORLD



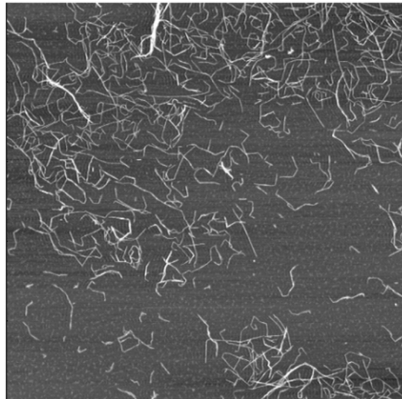
chemistryworld

# Nanocellulose - Across the Lifecycle

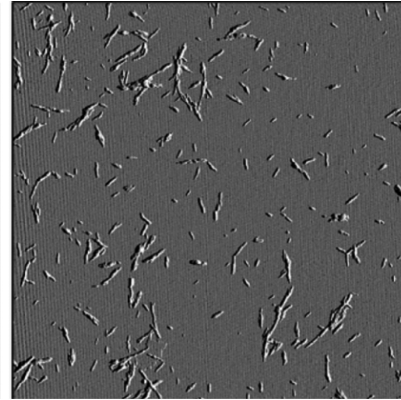
## Nanocellulose Production (Roman, Renneckar)



**Bacterial Cellulose**

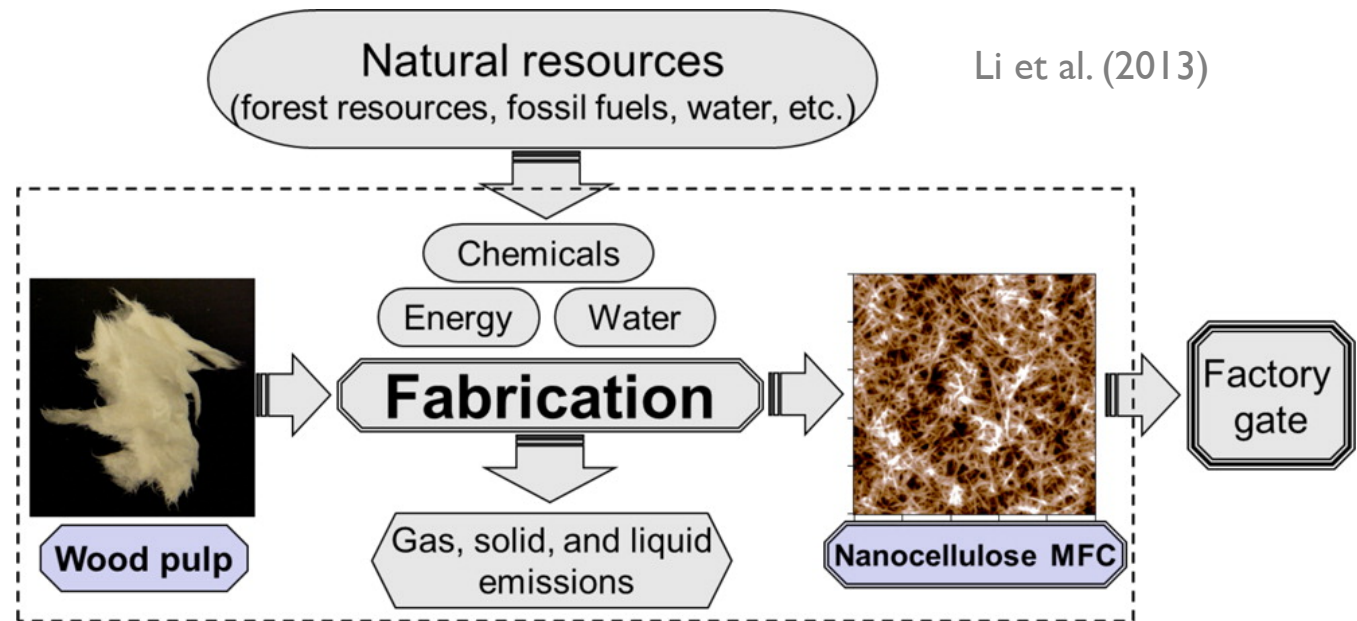


**Microfibrillated Cellulose**



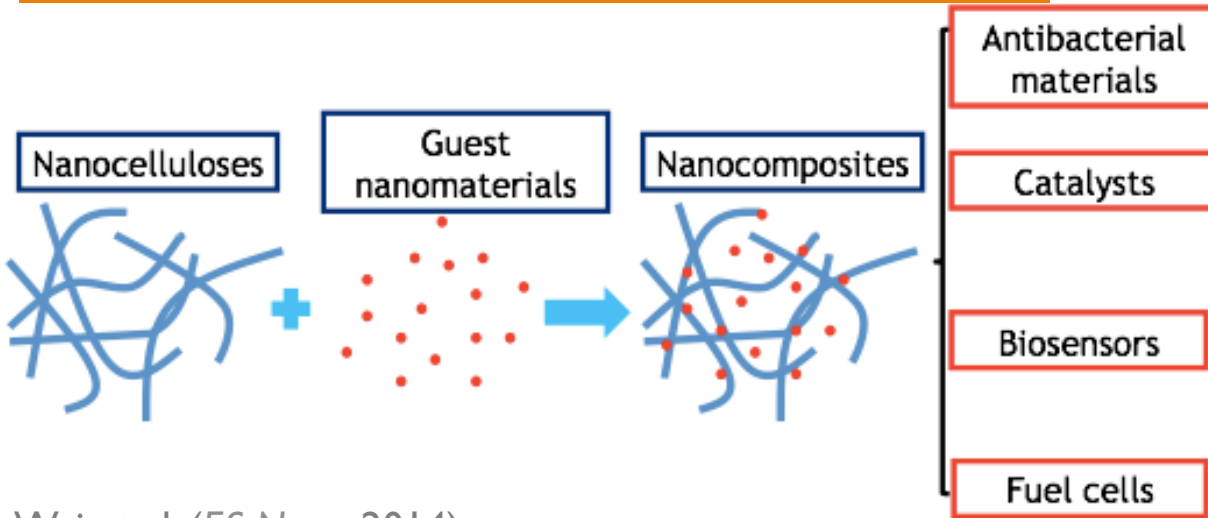
**Cellulose Nano Crystals**

## Life Cycle Assessment of Nanocellulose Production (Rennekar, McGinnis)

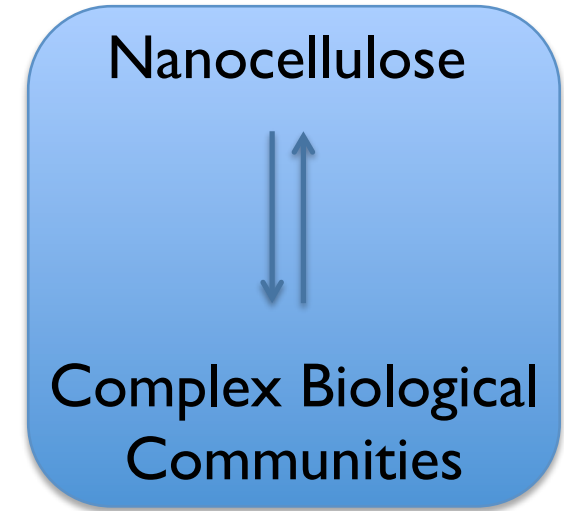


# Nanocellulose - Across the Lifecycle

## Nanocellulose Based Nanocomposites (Vikesland, Renneckar)

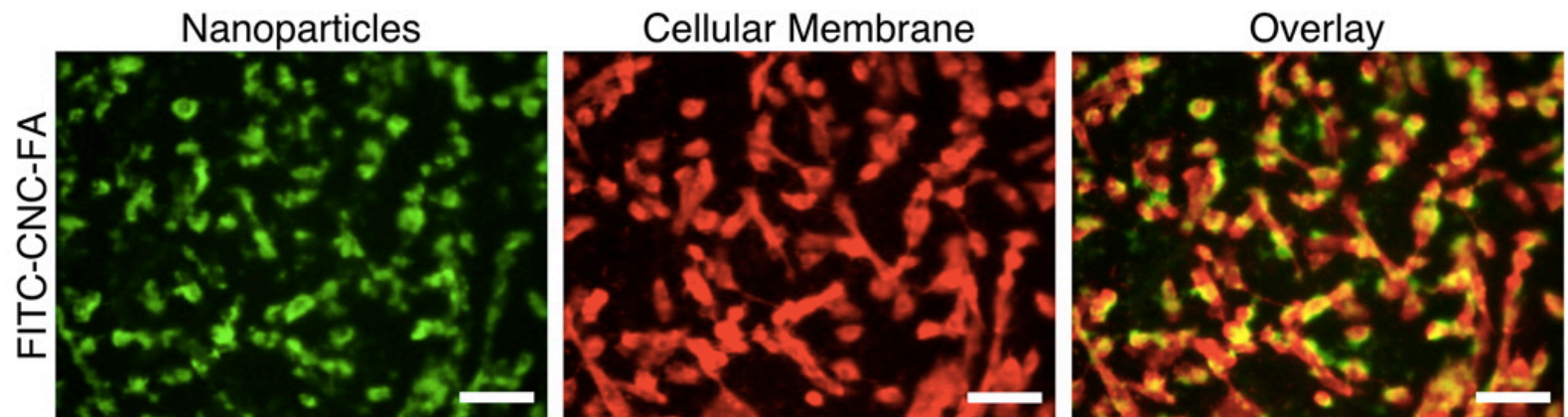


Wei et al. (*ES Nano*, 2014)



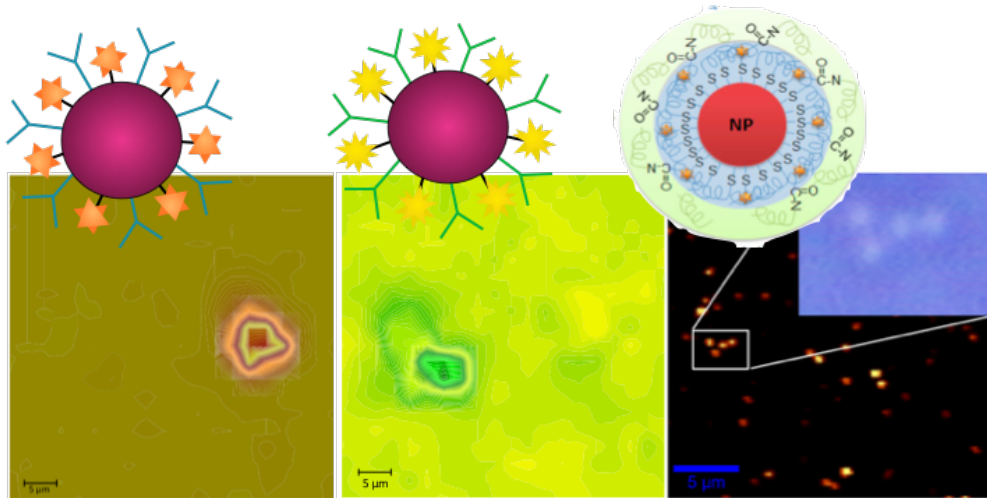
Dong et al. (2014)

## Cellular and Organismal Interactions (Roman, Pruden, Renneckar, Vikesland)



# Gold Nanoparticles – Implications and Applications

## Nanoparticle Based Pathogen Sensors (Vikesland, Pruden, Marr)



*Cryptosporidium parvum*    *Giardia lamblia*    *Staphylococcus aureus*  
 Antibody                      Antibody                      Aptamer  
 Rule et al. (2009 & 2010); Riquelme et al. (Submitted)

## Nanoparticle Fate in the Environment (Vikesland, Pruden, Bickford)

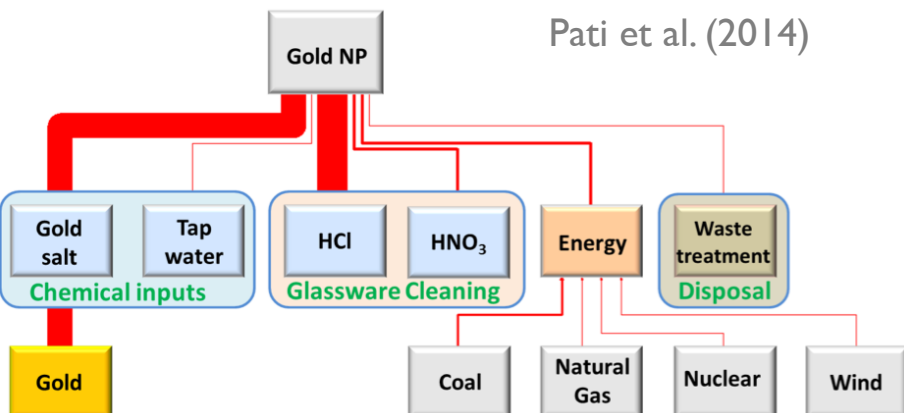


Organismal Uptake –  
 Hull et al. (2011; 2013)

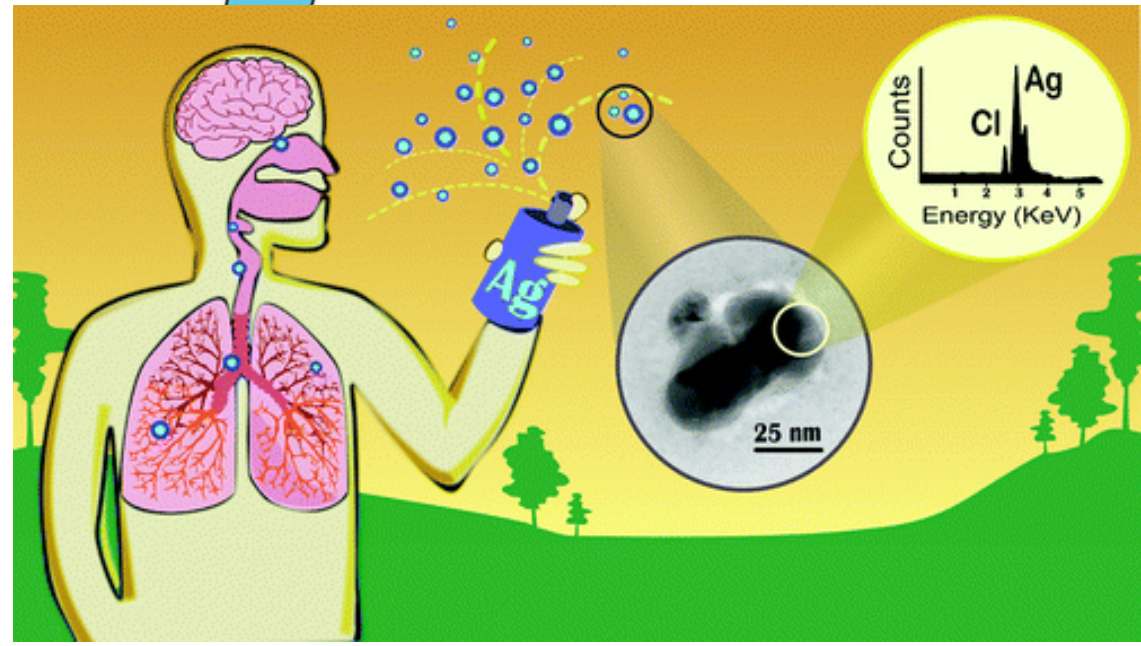
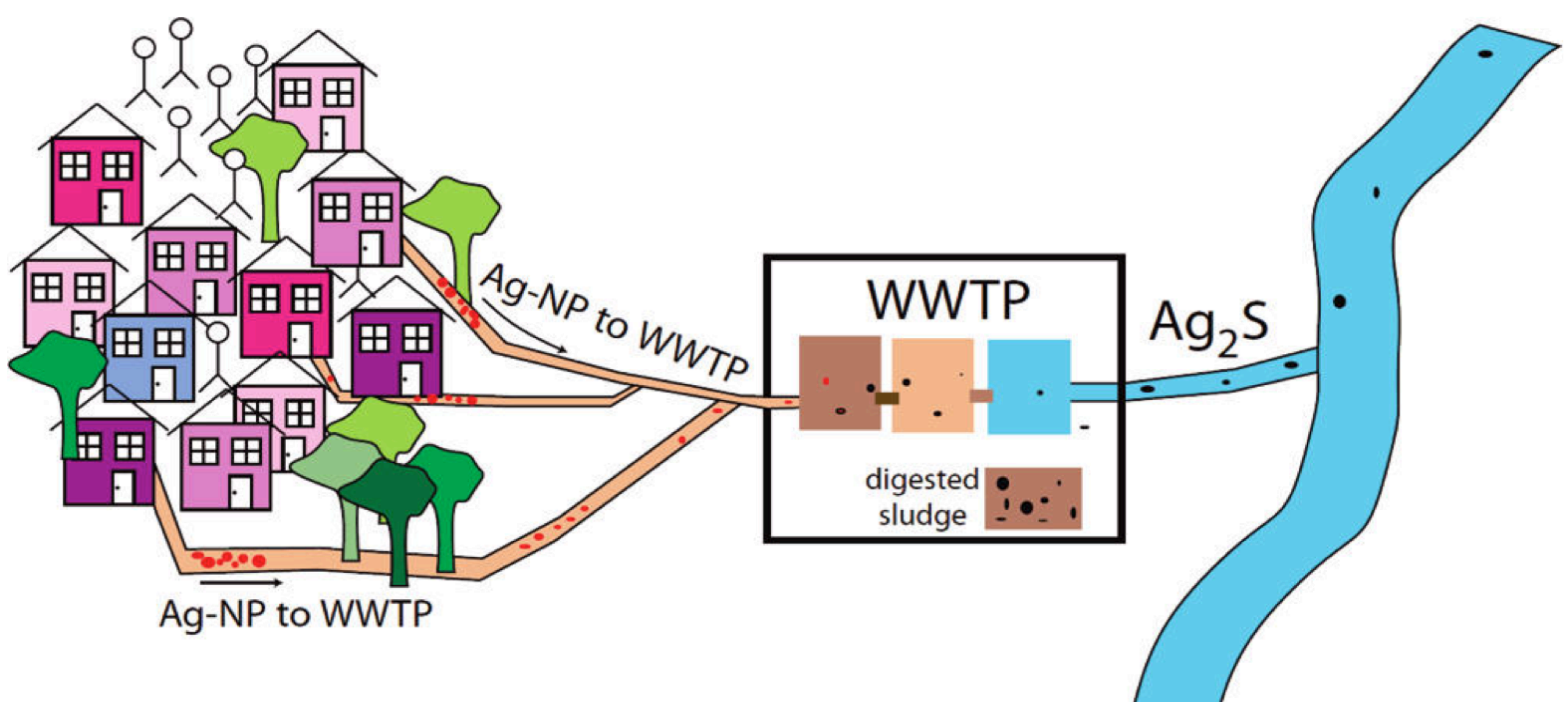


2D and 3D Nanoparticle Tracking – Chan & Vikesland (2014); Lahr et al. (2014); Detzel et al. (2013); Reese et al. (submitted)

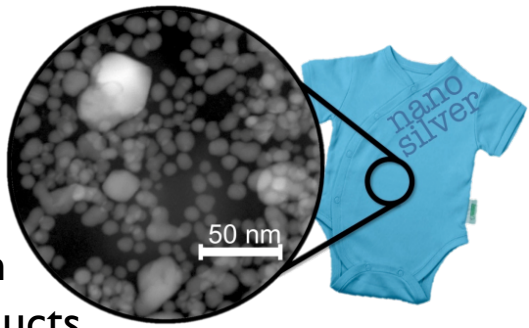
## Life Cycle Assessment of Production (Vikesland, McGinnis)



# Silver Nanoparticles – Engineered and Earth Systems



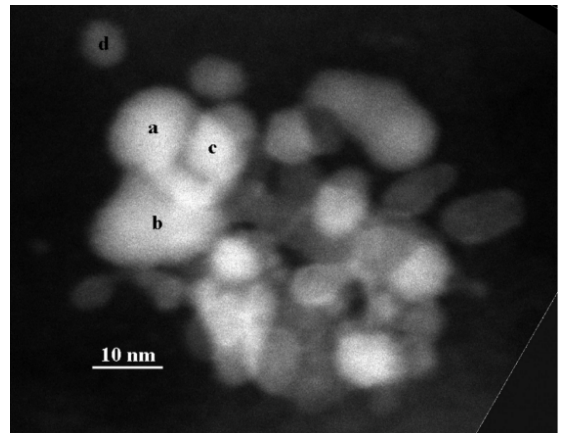
# Silver Nanoparticles – Engineered and Earth Systems



Release of nanosilver from consumer products

Quadros et al. (2010), (2011), (2013)

Discovery of silver sulfide nanoparticles in sewage sludge



Kim et al. (2010)

Nanosilver effects on antibiotic resistance genes and microbial communities in anaerobic digestion

Miller et al. (2013)  
Ma et al. (2014)

Nanosilver sulfidation in a full-scale wastewater treatment plant

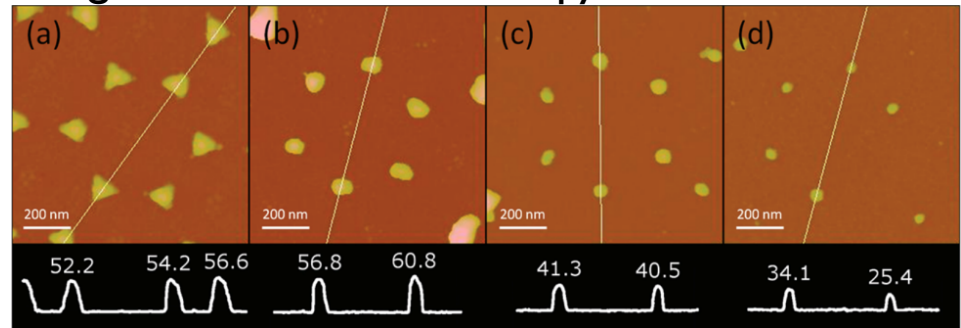


Kent et al. (2014)

Nanosilver impacts on disinfection byproduct formation in wastewater effluents

Metch et al. (to be submitted)

Nanosilver dissolution using atomic force microscopy



Kent et al. (2012)

# Keys to success

- Fruitful faculty-faculty interactions



- Fruitful student-faculty interactions

- Fruitful student-student interactions



All of these require good communication within and across disciplines.

“How do we make the world work for 100% of humanity in the shortest possible time through spontaneous cooperation without ecological damage or disadvantage to anyone?”

Buckminster Fuller



**VT Su N**  
Virginia Tech Sustainable Nanotechnology

[pvikes@vt.edu](mailto:pvikes@vt.edu)  
[@petervikesland](#)  
[@VTSuN](#)