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The Center for
Nanotechnology in Society
ARIZONA STATE UNIVERSITY

CNS Systematic Analysis Workshop

Urban NanoScape - Nanotechnology Expert Panel: Urban NanoScape Review

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1.0 Introduction

Thematic Research Cluster 2 (TRC-2) within the Center for Nanotechnology in Society at Arizona State University (CNS-ASU) is focused on addressing issues of nanotechnology embedded in urban environments. Nanotechnology is lauded for enabling society to become more sustainable. From Nobel Laureate in Chemistry, Richard Smalley (2006) to Diallo et al. (2011) the problems are described as "global sustainability challenges facing the world are complex and involve multiple interdependent areas." Yet, both assert that nanotechnology can be an enabling technology to address these issues. The American Chemical Society, feels that the "significant contributions that nanoscience is making toward sustainability" are the focus of a significant amount of research in chemistry (Weiss and Lewis 2010).

These claims appear to be aligned with sustainability science, an emerging science that is problem-focused and solution-oriented (Kates et al. 2001; Clark and Dickson 2003; Komijama and Takeuchi 2006; Jernecke et al. 2011; Wiek, Ness et al. 2012). In the last ten years, sustainability science created both theoretical and methodological frameworks to systematically address wicked problems (Rittel and Webber 1973; Ravetz 2006; Seager et al. 2011; Wiek et al. 2012). We are using the term *urban sustainability syndromes* to define the challenges facing our cities. However, the claims that nanotechnology can address sustainability challenges fails to recognize the true nature of urban sustainability syndromes. There are a number of reasons why. First, sustainability has been narrowly defined as an issue of natural resources (e.g. energy generation). This narrow definition fails to address the social dimension of sustainability, such as conflicts or economic valuations (Jernecke et al. 2011; Wiek et al. 2012). Second, there is little consideration paid to the underlying drivers that contribute to the problem. Our societal demand of inexpensive energy creates the cultural expectations that the plug in the wall will always work. Addressing energy generation does is in no way related to our cultural norms that demand electricity twenty-four hours a day. Third, nano-enabled solutions (and most technological fixes) are not considered as part of a suite of solution options, but are the initial response. Considering social changes or educational changes may prove more efficient (Sarewitz and Nelson 2008). Fourth, the use of technologies as both providers of benefits and creators of risk is rarely addressed. When addressing urban sustainability syndromes, we must ask will the nanotechnology reinforce or make the current situation worse, even as we attempt to solve the problem (Seager et al. 2011). We seek to understand the city environment that nanotechnology will be introduced into. Therefore, our first step is to understand the nature of the urban sustainability syndromes we are facing.

Cities are now home to more than fifty percent of the world's people and have started to address issues of sustainability through city-based actions (Svara 2011) and as a collective of global cities (C40 2011). Urban centers are the home to regional, state, and national decision-making bodies that comprise a complex network of institutions, resources, and actors taking actions to identify problems and craft solutions. Ross (2011) denotes that Phoenix is the globe's least sustainability urban region and is ripe for change. The ultimate goal of our research agenda is to prepare research that embeds nanotechnology into a suite of potential solutions to urban sustainability syndromes that warrant consideration and assessment by experts and stakeholders alike. In this way we attempt to operationalize anticipatory governance within the urban context using the perspective of sustainability science to assess, in real-time, emerging technologies, specifically nanotechnology (Guston, 2008; Karinen and Guston 2010; Wiek, Guston, van der Leeuw, et al. 2012; Wiek, Guston, Frow, et al. 2012).

2.0 Objectives

The four objectives for this workshop were shared with participants. The first was to have experts review the *Urban Nanoscape* produced by the research team through nanotechnology profiles from the Nanotechnology In City Environments (NICE) database. Secondly we sought to generate a prioritized list of the most promising urban nanotechnologies. The third objective was to identify benefits and potentially negative impacts of urban nanotechnologies. And our final goal was to continue building an urban nanotechnology governance community across the Arizona State University enterprise.

Additionally we held implicit goals for the workshop that were not only aligned with the singular research objective of TRC-2 but aligned with furthering the goals of the larger CNS research team. The workshop intended to train undergraduate and graduate students in the process of planning, structuring, facilitating, and capturing information through experiential learning during the course of the workshop itself. Further, the research team wanted to demonstrate and translate information between and among disciplinary researchers in an effort to facilitate future engagement and knowledge generation between disciplines. This furthers the center's goal of exploring new ideas, disseminating information, and seeding future discussions within the context of emerging technology issues and societal impacts. Our workshop proposed to research differently, by framing the research through the orientation of urban sustainability we can better understand the current state of the city environment and therefore take a more grounded approach in scenario construction, visioning exercises, and strategy building that are scheduled in future research years. And finally, by seeking engagement with the diverse disciplines represented, TRC-2 sought to grow the engagement effort of CNS and build bridges to new research communities and to play well with the scientists invited and build trust and gain mutual understanding on the issues of concern.

3.0 Workshop Design

Following Sarewitz and Pielke's (2007) supply-demand framework, we conceptualize urban sustainability syndromes as demand (as there is a need for society to address them) and nanotechnology as a potential supply (providing solution options). The goal is to identify the overlap between demand and supply, or in other words, *reconcile* to what extent demand for solutions to sustainability problems and supply of nanotechnology actually match (Sarewitz and Nelson 2008). Existing and proposed nanotechnologies have the potential to address a spectrum of challenges, but defining the intersection or overlap between demand and supply means identifying how nanotechnology 'solves' specific problems, with what impacts (intended and unintended), and whether or not other, more sustainable, alternatives exist (Wiek, Guston, van der Leeuw et al. 2012).

To understand which nanotechnology applications are emerging within the urban environment we focused our investigative lens on the Phoenix metropolitan area, of four hundred square miles with over four million residents. We have bound our spatial and temporal dimensions for our workshop to the current and near-term (0-10 years). A literature and media publication review of urban nanotechnologies, their functions, promised benefits, and potential risks preceded the workshop. To confirm and further develop our literature review we structured an expert workshop with nanotechnology scientists and engineers.

In an effort to gain perspective on the urban nanotechnologies, we invited experts in from a diverse set of disciplines that work with nanotechnologies in their active research in March 2011. Nine scholars from energy systems, materials sciences, water and waste treatment technology, environmental toxicology and risk assessment, transportation systems, and bioengineering attended the workshop. Although, we are not able to capture expertise from every sub-discipline of nanotechnology science and engineering, our intent was to elicit participation from a wide spectrum of disciplines in an effort to structure a broadly focused, yet technically grounded workshop.

To achieve the research objectives a collaborative and trans-disciplinary workshop was conducted following the structure and schedule detailed in table 1. Upon entry to the workshop, participants were first introduced both to CNS and TRC-2 broadly with background information and orientation in the plenary. Participants were then provided an overview of the workshop proceedings and expectations from the research team. This introduction and orientation provided context for the experts and a framework for them to offer their insights and contribute throughout the workshop.

Activities	Desired Outcome
Greeting & IRB Compliance Forms	IRB commitments met
Introduction	Workshop orientation
Urban NanoScape Visual Introduction	Orientation to scale & applications
1. Urban NanoScape table 2. Review domains and clusters of applications (individual) (5-10’) 3. Feedback Round (10’)	Validate and supplement Urban NanoScape Table
NICE Introduction	Introduction and orientation
1. Participants are assigned/select one (1) application to work on for next session 2. Peer-review of selected applications (individual) 3. Feedback Round	Validate and supplement NICE entries Validate and supplement the NICE metadata structure
Break	Finalize list & rest
Urban NanoScape at Gateway	Orientation to scale & applications
1. Prioritize applications: most impactful for urban sustainability (Introduction) 2. Ranking (individual voting) 3. Feedback Round	Prioritize top applications
1. Evaluating top prioritized applications / clusters (Introduction) 2. Benefits and negative effects (Impact and Affected Populations) 3. Synthesis discussion	Reflective engagement of beneficial and negative effects of priority applications
Wrap up and conclusion	Thank participants and close meeting

Table 1. Workshop Design. The table details the activities, desired outcome of the specific activity.

4.0 Outcomes

Activity 1.

The first activity’s goal was to validate the research team’s constructed Urban NanoScape (see Table 2) and elicit additional domains and applications from the participants (see Appendix 1). To orient the participants to this activity, the facilitator provided a brief visual introduction with images and captions describing how nanotechnology applications are emerging within the urban environment and to explain the research team’s definition of urban nanotechnology. The participants were provided a handout of the Urban NanoScape for their review and note taking. Participants were offered five (5) minutes to consider and reflect on the table, critically evaluating the domains and nanotechnology applications. After the individual reflection and critic, the facilitator opened the floor to participants to verbally state, in the plenary, what additional domains were needed, if domains were incorrectly termed or grouped, and offer additional nanotechnology applications that had not been captured by the research team. At the conclusion of the feedback round in the plenary, a research team member signaled the end of this activity and transitioned to the introduction of the following activity.

Activity 2.

Next the participants were provided a verbal introduction to the origin and scope of the NICE database. This activity allowed for individual review and critic of the material, which many participants took advantage of, while others in the flow of open discussion and discourse questioned the objectives of the NICE database and the targeted audience. Although questions about the NICE database objectives and targeted audience had been initially addressed in the orientation, these questions opened a discussion that lead to a number of suggestions for the research team in phrasing and structuring the orientation of the NICE database. Those recommendations included; i. interfacing with existing organizations and networks of nanotechnology scientists and engineers (eg. Nanohub.org); ii. offering space for contributors to the NICE database to have personalized and promotional links or biographies and; iii. incentivizing contributions to the NICE database through the inclusion of patent information. Establishing links to existing databases or social networks would greatly advance the prominence of the database. Database and social networks suggested include: Woodrow Wilson's Nano-products Database, Patent Information Links, NanoHub, Contributor Pages with personal links.

Participants felt collectively that the database should not be entirely open to content additions, edits, or deletions. The participants expressed that the contributions or corrections should be moderated, but not peer-reviewed. Peer-review was felt to be too lengthy and tedious. The moderator was defined as a filter through which content and database structure could be controlled, but not overly restricted.

In respect to the improvements and comments on the NICE database as a functional tool, the participants suggested that information regarding risk and reactivity for emergency response personnel be included. Furthermore, links to MSDS information or regulatory information on the handling, storage, and disposal should be linked through the database. Further the suggestion was made that CNS perhaps create a risk labeling or categorization scheme. Additionally, information on the chemical reactivity of the nanotechnology was suggested to the research team. This call for risk labeling and risk identification was highly important to certain participants. Primarily the dialogue focused on methods to attract people to the NICE database and adding information related to risk assessment, risk labeling, materials safety, and reactivity.

Participants did not individually reflect on the data quality of the individual nanotechnology applications presented within the activity. The researcher responsible for a significant portion of the data entry was in the workshop and that might have contributed to reluctance on the part of the participants to openly critique that individual's work. Additionally, the robust and lengthy dialogue on the overall database structure, moderation of content, database objectives, and motivating factors for potential contributors dominated the time allotment for the activity. Although, it is unfortunate that the data entry was not reviewed in detail, future opportunities will allow for initial data entry review. At the conclusion of this activity, participants took a short break allowing the research team to update the nanotechnology applications list to included new information gained from the first activity.

Urban Nanoscape 2010-2020					
Commercial, Industrial, Residential, and Educational & Recreational Buildings	Energy and Communication Infrastructure	Water and Waste Infrastructure	Transportation Infrastructure	Consumer & Household Products	Food Production & Distribution
Dynamic UV reducing Glazes (LaBn6)	Enhanced Durability Coatings (TiN)	Contamination Adsorbtion Particles (FeO)	Enhanced Concrete (CNTs)	Sun Protection (TiO2, ZnO)	Security & Product Tagging (RFID)
Enhanced Durability Coatings (TiN)	Security & Product Tagging (RFID)	Desalinzation	Air Purification: Catalytic Converters (Pd, Pt)	Security & Product Tagging (RFID)	Catalytic Converters (Pd, Pt)
Self Cleaning Surfaces (TiO)	Smart Phones/Computers	Water Filtration	Photo Voltaics (CdTe, GaAs)	Photo Voltaics (CdTe, GaAs)	Water Filtration
Enhanced Concrete (CNTs)	Photo Synthesis	Nano Biocides	Self-Cleaning Glazes (TiO)	Anti-Microbial Wear (Ag)	Microbial detectors in Food
Photo Voltaics (CdTe, GaAs)	Thermal-Electrics	Nano Sorbents	Enhanced Durability Polymer Nano-composites	Smart Phones/Computers	Anti-Microbial LEDs
Water Filtration	Energy Storage Systems	Anti-Microbial Coatings	LED Lighting	Water Filtration	
Anti-microbial Coatings	LED Lighting	Enhanced Durability PVC	Energy Storage Systems	Anti-microbial Coatings	
Nano-enhanced Sealant	Fuel Cells	Anti-Microbial LEDs		Insulating Aero-gel	
Energy Storage Systems				LED Lighting	
Enhanced Durability Polymer Nano-composites				Energy Storage Systems	
LED Lighting					

Table 2. Urban Nanoscape. Above is the table presented to participants detailing the current to near-term (0-10year) applications of nanotechnology by domain. Blocks highlighted in yellow are detailed in the Nano In City Environment (NICE) database.

Activity 3.

After a short break, participants rejoined the plenary for orientation and introduction to the next activity. With an extended listing of nanotechnology applications developed initially by the research team and built upon within the first activity, an activity to prioritize the nanotechnology applications was conducted. Prior to initiating the prioritization, participants were introduced to considerations of how nanotechnology might be challenged to assist lower socio-economic communities. This perspective was intended to balance and moderate an entirely utopian and techno-optimistic outlook during the prioritization activity. The potential of nanotechnology to address socio-economic conditions within urban environment created a certain level of hesitation and confusion prior to the commencement of the prioritization.

The structure of the prioritization included a randomized listing of the nanotechnology applications projected onto the wall. Participants were given five (5) sticky notes as proxies for votes to cast in setting an initial prioritization. Participants asked repeatedly for clarification on what the criteria for the voting from the facilitators. Participants were instructed to approach the whiteboard and place their votes next to the nanotechnology application that they felt would create the highest benefit for society broadly. All voters could see votes accumulate and their voting could be observed, this was not a closed balloting session. At the conclusion of this activity, the research team had a list of the top priority nanotechnology applications as viewed by the participants.

Ranking	**Functional Application**
1	Energy Storage Systems
2	Food Additives
3	Photovoltaic Cells
4*	Industrial Catalysts
4*	Medical Apparatus
4*	Detectors
4*	Water Filtration
8	Water Desalinization
9*	Air Pollution Control
9*	LED Lighting (Nano Enhanced)
9*	Fire Retardants
9*	Self-cleaning Surfaces

Table 3. Prioritized Urban Nanotechnologies. Table lists the top twelve functional nanotechnology applications as ranked by the workshop participants. *Four applications tied for fourth and ninth place.

Activity 4.

With a prioritized list, the research team sought to engage the science and engineers in an activity to evaluate the top three (3) nanotechnology applications. Each participant was provided with a handout (see Appendix 2). The handout instructed the participants to summarize, positive impacts and affected populations (groups) from the top three nanotechnology applications. Individuals were provided with five to ten (5-10) minutes to express their ideas on the handouts. After the individual period of writing and reflection was concluded, the facilitator initiated a discussion. Participants were asked to state the nanotechnology application, the benefits, benefiting population, negative impact, and negatively affected population. In the plenary, facilitators captured responses on the whiteboard for consideration and discussion.

Participants quickly understood the context and instructions for this activity. One participant when introduced to the activity, stated (in effect), “we invent all technology for the rich, of course the poor are harmed or disadvantaged by new technology. We are providing trickle down technology solutions for the poor. We don’t specifically design technology for poor people, they don’t have money to buy it.” It was the research team’s explicit intent to structure a space for scientists and engineers to explore this type of thought. The worksheet challenges the paradigm that all technological solutions are ‘goods’, without regards to the ‘bads’ – see clustered responses in table 4. After this initial outburst, participants took seriously the task of critically evaluating positive and negative aspects of technological solutions. Every single participant expressed at least one negative impacts and negatively affected population on their individual worksheet.

Then a discussion was opened and continued until the time allocated for the workshop came to a conclusion. At the conclusion of the workshop, participants were verbally thanked for their participation and asked to express one thing they learned and one thing they would like to see in future workshops or know more about in the future. Concrete ideas were discussed and captured, but more importantly, the participants and facilitators entered a robust dialogue that continued past the allotted time of the workshop. Numerous participants continued the discussion after the formal conclusion of the workshop.

	Benefits	Benefited population	Negative impact	Impacted population
Energy Storage System	Greater capture of solar energy	Owners of PV cells	Increased disposal of batteries and informal recycling	Population near hazardous disposal sites and performing informal recycling.
	Increased mobility of devices	Electronics users	Material scarcity in rare earth metals	Populations near mining and processing facilities
	Increased efficiency	Electronics users	Loss of invested capital and jobs in fossil fuels	Populations invested in oil and coal-based industries.
Photovoltaic Cells	Decreased C02 emissions	All people and ecosystems impacted by global climate change	Material scarcity in rare earth metals	Populations near mining and processing facilities
	Increased capture of solar energy	Owners of PV cells	Waste generated by PV cell disposal	Populations near disposal and informal recycling sites
	Decreased reliance on fossil fuels	All people and ecosystems impacted by global climate change	Loss of invested capital and jobs	Populations invested in oil and coal-based industries.
	Decreased energy costs	Vulnerable socio-economic communities	Loss of profits in traditional energy.	Populations invested in oil and coal-based industries.
Food Additives	Increased shelf life	Consumers and marginal food producing lands and populations in food deserts.	High consumption and therefore, high risk potential (if found to be toxic)	All consumers and ecosystems exposed to toxics. Families eating high volumes of processed foods
	Decreased food prices	Vulnerable socio-economic communities	Farm-based revenue	Farmers
	Decreased pesticide use	Ecosystems impacted by pesticide use	Pesticide firms lose revenue	Company owners and employees
	Increased flavor & taste	Consumers preferring these foods	Increased reliance on processed food	Families eating high volumes of processed foods
	Increased nutrition	Consumers	Increased reliance on processed food	Families eating high volumes of processed foods

Table 4. Benefits and Impacts of Urban Nanotechnologies. Top functional nanotechnology applications evaluated for benefits, benefiting populations, negative impacts, and negatively affected people.

5.0 Discussion

The initial meetings, introductions and kick-off of the workshop yielded numerous first-time introductions within and among the various disciplines of scientists present. This informal process spurred an environment of both engagement and excitement for the opportunity presented to work collaboratively.
The introduction and orientation of the participants to both the project and to the first activity resulted in a strong level of interest, boundary questions, and a few 'ah ha' moments (moments of understanding). For many of the participants the boundary of the city as a lens through which nanotechnology applications would be viewed was confusing. Placement of the technological applications within a context, any context outside of their prescribed placement of the technology resulted in numerous and lengthy exchanges. Negotiating this boundary reoccurred through the workshop, but provided a communication mechanism through which participants and the facilitating research team worked. The boundary negotiation is reflected in the suggestion that additional urban domains, not present on the NanoScape table, should be included. Participants offered increasing the NanoScape domain categories to include: Medical Practice/Health Care, Industrial Processes/Manufacturing, and Innovation Space/Innovation Processes. Many of these categories had been previously considered by the research team and will potentially redefining the urban NanoScape. Additionally, participants wanted to fundamentally separate the domains of communication and energy infrastructure. That suggestion mirrored previous discussions and negotiations held internally by the TRC-2 research team.

6.0 Conclusion

The activity structure, focused on outcomes, offered an opportunity to achieve the goals of the workshop; i. review "Urban Nanoscape" produced by the research team through nanotechnology profiles from the NICE database; ii. generate a prioritized list of the most promising urban nanotechnologies; iii. identify benefits and potentially negative impacts and; iv. building an urban nanotechnology governance community across ASU. The workshop structure provided the context, orientation, and content for a collaborative and engaged participation. Detailed comments and critiques of NICE database were received, constructive feedback on the goal, focus, and differentiation attributes of the database structure. Further the final activity prompted a robust and highly interactive discussion on the positive and negative aspects of nanotechnology applications as become embedded within various socio-economic communities and conditions.

In the process of accomplishing these explicit goals, the workshop certainly achieved many of the larger CNS goals, not explicitly stated to participants; i. training undergraduate and graduate students in collaborative knowledge generation and workshop preparation, execution, and synthesis; ii. demonstrated and translated, in real-time, information between and among formerly isolated and independently oriented disciplinary actors; iii. exploration of new ideas, disseminated information and seeded future engagement through constructive and coherent activities; iv. framed the research through the orientation of urban sustainability in a context both available and understandable to the participants, to which they could strongly contribute their expert perspectives; v. the workshop built new bridges across campus to disciplines previously not engaged within CNS; vi. laid the foundation through trust, salience, and co-production of knowledge for engaging these participants in a longer-term iterative research agenda.

In summary, the explicit goals set by the research team for the workshop were met through the structure and execution of activities. The pre-workshop planning effort to consciously orient each activity toward an outcome that lead naturally into the proceeding activity provided strong continuity and content. This continuity and content allowed for smooth transitions between activities offering progressively deeper levels of engagement from both participants and facilitator-researchers. Herein, this initial engagement opportunity provided both the participants and the research team a space to build trust in a cooperative and open setting. It will be our express intent to build upon this trust throughout the term of the project and expand the network of interested and contributing parties to TRC-2 and to CNS as a whole entity.

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8.0 Appendix

Appendix 1. List of additional nanotechnology applications added by participants.

- Nano-Lasers
- Distributed energy storage
- Food additives
- Distributed energy generation
- Water Treatment (filters, membranes, desalinization)
- Aerosols capture
- Emergency Responder Communications
- Braking systems
- photo-catalysts
- industrial catalysts
- Nanowires
- Entertainment enhancement
- Fire Retardants
- Solid Waste

Appendix 2. Document used to get participants to consider benefits, benefiting populations, negative impacts, and negatively affected populations.

Expert Workshop: Urban Nanotechnology Application
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Urban Nanotechnology Applications in Phoenix (Metropolitan Area)
Temporal Dimension: Current – near future (0-5 years).
Instructions
Please list in the following table the 5 most impactful nanotechnology applications, as previously ranked by the participants, in the left hand column. For each application we are asking that you summarize, positive impacts and affected populations (groups) from that application. Then we are interested in unintended consequences that might result in negative impacts and affected populations (groups). Please write clearly as these sheets will be collected and transcribed for future activities by the research group.

Urban Nanotechnology Application	Benefits	Benefited Population	Negative Impact	Negatively Affected Population