

***The Engines of Growth:
Technology Foresight for Sustainable
Economic Development***

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Returning *Prosperity* to America's *Heartland*

NIU Center for Governmental Studies

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RAND's 2020 Technology Foresight Study



- **Global technology trends and applications**
 - **Social, political, economic, environmental, personal, regional, international impacts**
- **Broad spectrum of outlooks, testimonies, foresights**
 - **Range of future possibilities—not single prediction or scenario**
 - **Regional needs and country capacities to acquire and implement technology applications**
- **Available at:**
 - **www.rand.org/pubs/monographs/MG475 (Executive Summary)**
 - **www.rand.org/pubs/technical_reports/TR303 (Full Report)**

How to Focus Technology Foresight on Economic Development

- **Emphasize applications, not technologies**
 - Applications provide functions for users
 - For example, cheap solar energy rather than organic photovoltaics
- **Evaluate societal impact if implemented**
 - What does it improve or enable?
 - What performance level is needed?
- **Evaluate technical feasibility**
 - Is it plausible based on the literature and according to domain experts?
 - Will there be a commercial product by 2020?

How to Focus Technology Foresight on Economic Development (continued)

- **Evaluate implementation feasibility**
 - **How large is the market?**
 - **Does the technology application raise significant public-policy issues?**
- **Is global diffusion likely?**
 - **Will this technology application appeal to global markets?**
 - **Is it restricted by industry, country, region, or societal characteristics?**

How We Identified Technology Applications

- **White papers by domain experts**
 - **Status today, potential by 2020, applications and implications**
 - **Separate papers on biotechnology, nanotechnology, materials technology , information technology**
 - **Documented with extensive references to the technical and popular literature**
- **Technology applications collected from the white papers, subjected to detailed review based on available data and literature**

The Technology Applications We Found Highlight an Interdisciplinary Global Technology Revolution Affecting All Aspects of Life

- **Biotechnology**
 - Identify, understand, manipulate, improve, and control living organisms (including ourselves)
 - Nano-enabled sensing and nanoscale materials
 - *Drug delivery, tissue engineering, implants and prostheses*
- **Information availability and utility**
 - Seamless integration into society
 - *Ubiquitous access, wireless, multifunctional devices (cameras, RFID)*
- **Smart materials, nanotechnologies**
 - Integration of function with structure
 - *Fabrics, fibers, membranes, energy conversion and storage*
 - Continued miniaturization and increased functionality
 - *Sensors, networks, tracking and locating*

Some Biotechnology Trends and Applications to 2020

- **Many different bioassays on a sample at once**
 - **Rapid analyte identification from very little material**
 - **Medical diagnoses and forensic evaluations**
- **Personalized medicine, based on large databases of patient information and disease states**
 - **Rapid and parallel gene sequencing**
- **Development of genetically modified (GM) insects**
 - **Pests that produce sterile offspring or that do not carry or transmit disease pathogens**
- **Targeted drug delivery to organs or tumors**
 - **Molecular-level design and recognition**

Some Nanotechnology Trends and Applications to 2020

- **New families of chemical and biological sensors**
 - **Miniaturized, highly sensitive and selective**
 - **Individually worn sensors, especially for military and emergency personnel**
- **Capability for widespread human and environmental surveillance and monitoring**
- **Improvements in battery power management and capacity**
- **Wearable personal medical monitoring devices**
 - **Data recording and communications capability**
- **Functional nanostructures for**
 - **Controlled drug delivery**
 - **Improved performance of implants and prosthetic devices**

Some Materials Trends and Applications to 2020

- **Fabrics that incorporate power sources, electronics, and optical fibers**
- **Clothes that respond to external stimuli**
 - **Temperature changes**
 - **Presence of specific substances**
- **Nanostructured coatings and composite materials**
 - **Greatly enhanced strength, toughness, wear resistance, corrosion resistance, biocidal capabilities**
- **Water purification and decontamination systems**
 - **Nanostructured membranes and filters with tailored activity**

Some Information and Communications Technology Trends and Applications to 2020

- **Wireless Internet available worldwide to middle and upper classes**
 - Including developing countries and rural areas
- **Wearable computers**
 - Control of medical devices, appliances, entertainment systems
- **Massive personal databases (hopefully with robust security)**
 - History and log of information viewed or processed
 - Medical records and genomic information
- **Radio-frequency identification (RFID) tags**
 - Track commercial goods, consumer buying patterns, and even individual movement—security, targeted advertising

The Scheme We Used to Assess Technology Applications

- ***Metric 1 (Simple counting: 0 to 12)***
 - How many societal sectors will it impact?
 - Food, Water, Land, Population, Governance, Social Structure, Energy, Health, Economic Development, Education, Defense/Conflict, Environment/Pollution
- ***Metric 2 (Scale from -2 to +2)***
 - Will there be a commercial product by 2020?
- ***Metric 3 (Scale from -2 to +2)***
 - What is the market size (large, medium, niche)?
 - Will it raise significant public policy issues?
- ***Metric 4 (Binary scale, 0 or 1)***
 - Will diffusion be global (or moderated in some way)?

Assessment Based on Sum of Metrics Yielded “Top 16” of 56 Technology Applications for 2020

- 1. Cheap solar energy**
- 2. Rural wireless
Communications**
- 3. Ubiquitous info access**
- 4. Genetically modified crops**
- 5. Rapid bioassays**
- 6. Filters and catalysts**
- 7. Targeted drug delivery**
- 8. Cheap, autonomous
housing**
- 9. Green manufacturing**
- 10. Ubiquitous RFID**
- 11. Hybrid vehicles**
- 12. Pervasive sensors**
- 13. Tissue engineering**
- 14. Improved diagnostic and
surgical methods**
- 15. Wearable computers**
- 16. Quantum cryptography**

+ Internet (*for purposes of comparison*)

We Considered These Drivers for or Barriers to Sustainable Use of Technology Applications

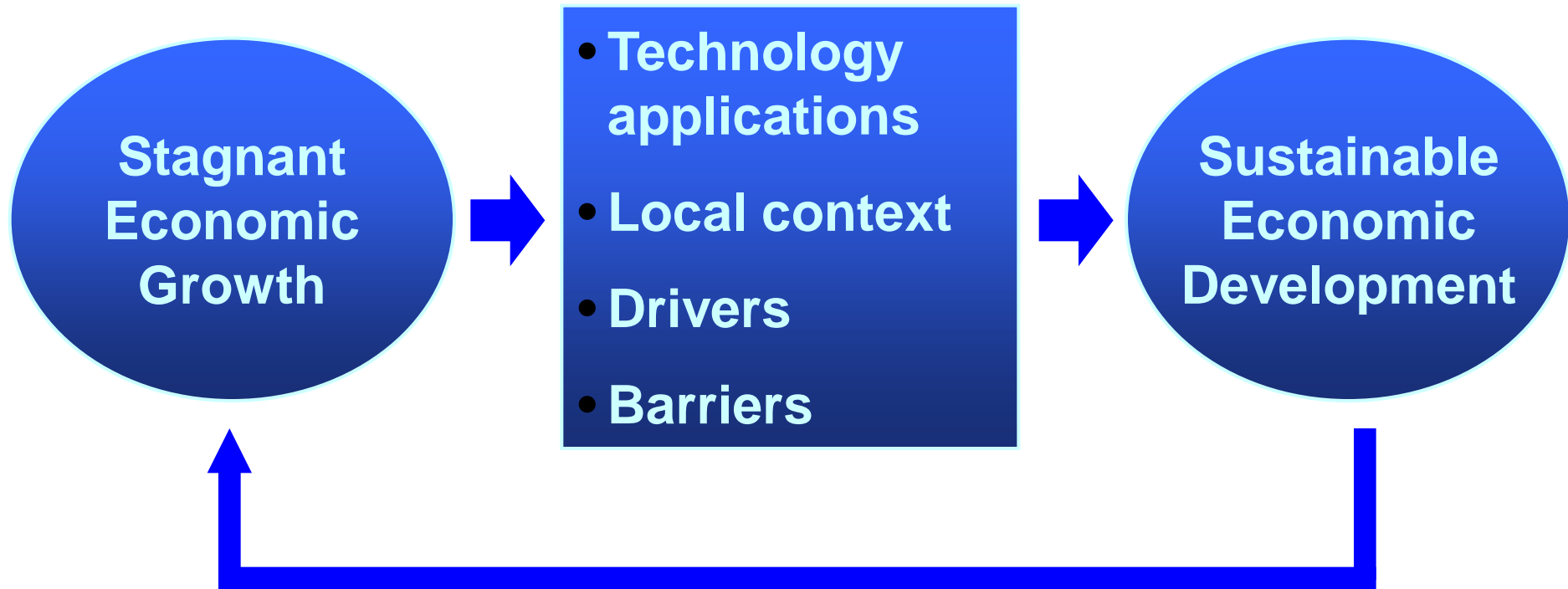
- a. Cost/Financing**
- b. Laws/Policies**
- c. Social Values, Public Opinions, Politics**
- d. Infrastructure**
- e. Privacy Concerns**
- f. Resource Use and Environmental Health**
- g. Investment in R&D**
- h. Education and Literacy**
- i. Population and Demographics**
- j. Governance and Stability**

How Decision-Makers Can Use Technology Foresight

- **With a given *time horizon*, technology foresight identifies**
 - **Technology applications with potential for sustainable economic development**
 - **Technical feasibility and possible actions to increase it**
 - **Implementation feasibility and possible actions to increase it**
 - **Capacity development needs to strengthen drivers and reduce barriers to achieving development goals**

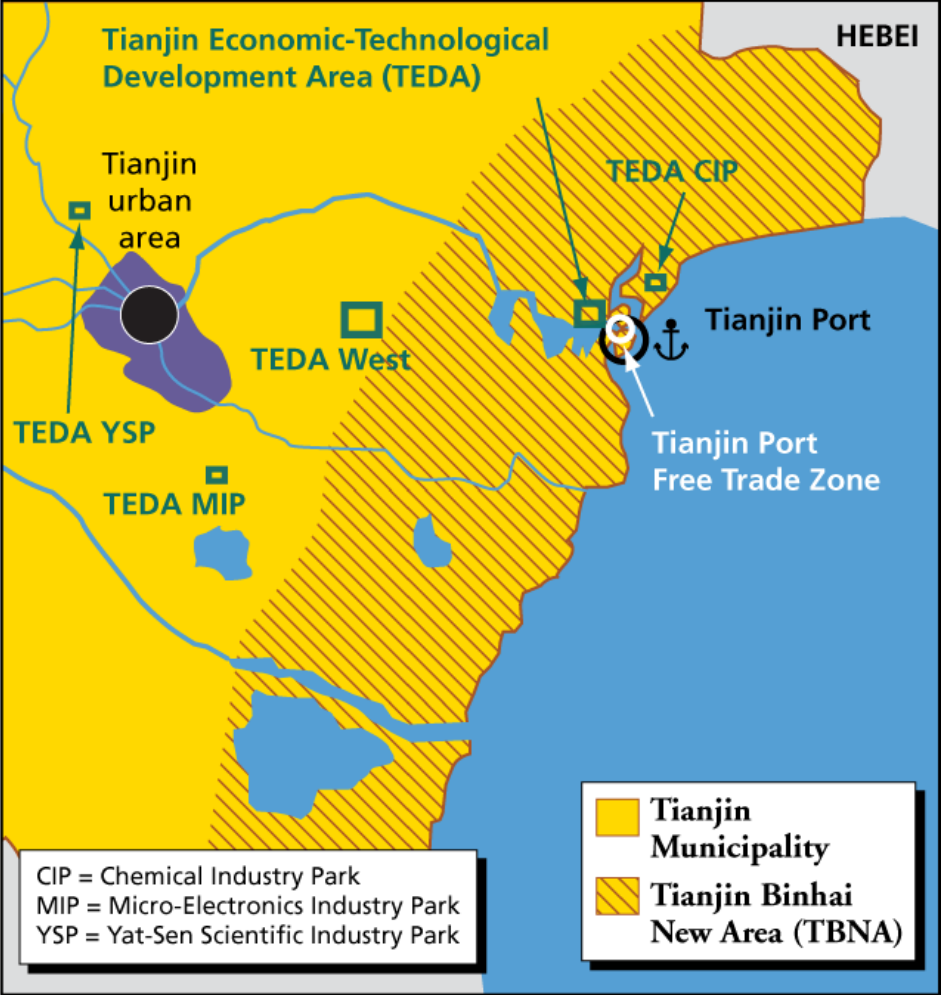
The Local Context is Critical to Identify and Address Capacity Needs

Technology Foresight



Address problems within the local context

The Case of TEDA & TBNA in China Offers a Vivid Example...



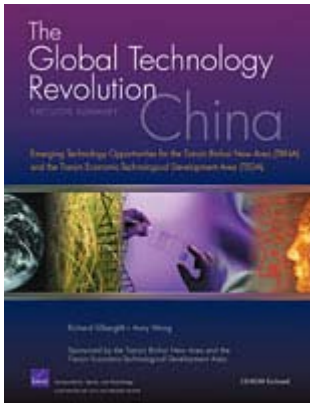
- TEDA and TBNA were developing a strategic plan to use technological innovation to drive economic growth

NOTE: Composite map draws from TBNA and TBNA-TEDA sources and *Asia Times*.
RAND A8097-2

The Case of TEDA & TBNA in China Offers a Vivid Example...

- **As part of that effort, they approached RAND to conduct a technology foresight study**
 - **Identify the most promising emerging technology applications (TAs) for TEDA and TBNA to pursue**
 - **Recommend a strategy and action plan for each TA**
- **RAND started with the 2006 RAND foresight analysis of the world's top emerging TAs by 2020**
- **It combined this with rigorous analysis of the local context in TEDA, and China more broadly**
 - **Current realities, circumstances, and issues**

RAND's Technology Foresight Study for TEDA and TBNA



- **Most promising technology applications for TEDA and TBNA**
 - Beginning with the 2020 TAs and taking into account their mission, China's pressing national needs, drivers, barriers, and available capacity
- **For each of the most promising TAs**
 - An updated foresight, including market status, identification of emerging trends and key players, drivers and barriers, local capacity
 - A three part action plan: research and development (R&D), manufacturing, commercialization
- **Available at:**
 - www.rand.org/pubs/monographs/MG776 [Executive Summary (in English and Chinese)]
 - www.rand.org/pubs/technical_reports/TR649 [Full Report (also available in Chinese)]

For TBNA and TEDA, Seven TAs Could Spur Sustainable Economic Development



Cheap solar energy



Green manufacturing



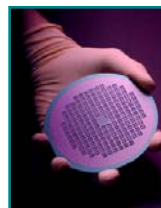
Advanced mobile communications & radio frequency identification



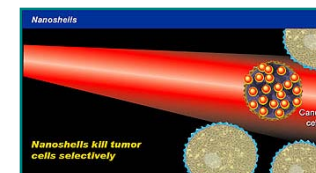
Electric & hybrid vehicles



Rapid bioassays



Membranes, filters, & catalysts for water purification



Molecular-scale drug design, development, & delivery

For TBNA and TEDA, Seven TAs Could Spur Sustainable Economic Development



Cheap solar energy

Solar energy systems inexpensive enough to be widely available to developing and undeveloped countries, as well as disadvantaged populations



Green manufacturing



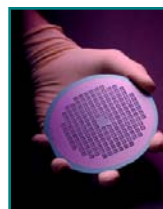
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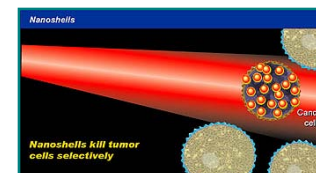
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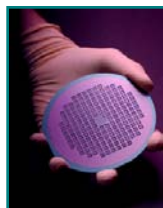
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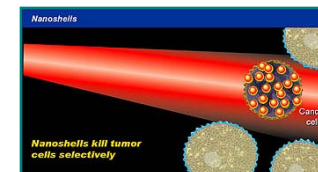
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Green manufacturing



Electric & hybrid vehicles



Molecular-scale drug design, development, & delivery

- Multi-functional platforms for sensing, processing, storing, and communicating information
- Radio Frequency Identification (RFID) involves technologies used to store information and transmit it wirelessly over short distances

For TBNA and TEDA, Seven TAs Could Spur Sustainable Economic Development



Cheap solar energy



Green manufacturing



Advanced mobile communications & radio frequency identification

Rapid tests to detect the presence or absence of specific biological substances, with the ability to perform multiple tests simultaneously



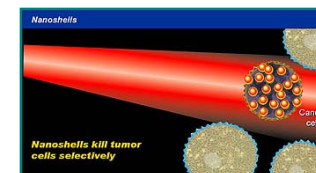
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Cheap solar energy



Advanced mobile communications & radio frequency identification



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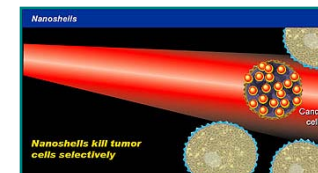
Membranes, filters, & catalysts for water purification



Green manufacturing



Electric & hybrid vehicles



Molecular-scale drug design, development, & delivery

Novel materials to desalinate, disinfect, decontaminate, and help assure the quality of water resources



For TBNA and TEDA, Seven TAs Could Spur Sustainable Economic Development



Cheap solar energy



Green manufacturing



Advanced mobile communications & radio frequency identification

Biomedical therapies and diagnostics with improved effectiveness and fewer unintended consequences



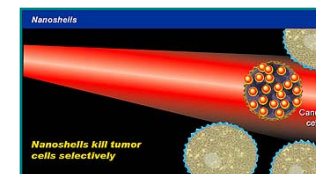
Electric & hybrid vehicles



Rapid bioassays



Membranes, filters, & catalysts for water purification



Molecular-scale drug design, development, & delivery

For TBNA and TEDA, Seven TAs Could Spur Sustainable Economic Development



Cheap solar energy



Green manufacturing



Advanced mobile communications & radio frequency identification

Automobiles available to the mass market with power systems that...

- Combine internal combustion and other power sources
- Recover energy during braking



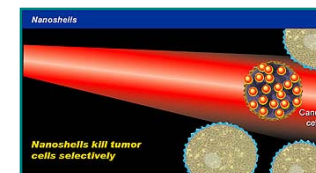
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Membranes, filters, & catalysts for water purification



Molecular-scale drug design, development, & delivery

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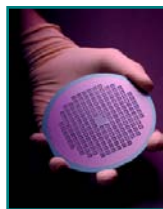
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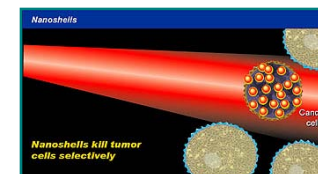
Green manufacturing



Electric & hybrid vehicles

The development and use of manufacturing processes that...

- Minimize waste and environmental pollution
- Optimize the use and reuse of resources



Molecular-scale drug design, development, & delivery

The Seven TAs Build on Two Key Global Trends in Technology and Industry

- The vast majority of the TAs identified in RAND's 2006 foresight involve...
 - Micro- or nano-scale advances
 - Integration of bio, nano, information, and materials technology

Six of the TAs for TBNA and TEDA involve micro- or nano-scale technology

-
- Industry and consumers today are moving clearly in the direction of green processes and technologies

Four TAs are focused on using energy, water, and other resources efficiently

Cheap Solar Energy: Why Is It Important to TBNA and TEDA?

- **The market demand for solar energy is growing rapidly--44% average growth rate over the past five years**
- **Worldwide competition to lower the cost of solar energy is increasing**
- **China needs to promote energy growth, while reducing the impact on the environment and improving air quality**



Source: Nanosolar, Inc.

Printable Solar Collector



Power Plastic®

Source: Konarka Technologies

Plastic Solar Collector



Existing Local Capacity

- **A research group at Nankai University is working on thin-film silicon (2nd generation solar) materials**
 - **This group has collaborated with the Beijing Solar Energy Institute**
- **The China National Academy of Nanotechnology and Engineering (CNANE) in TEDA has the capacity required for R&D of 3rd generation solar materials**
 - **Technical and instrumentation capacity on the nanoscale level**



Drivers and Barriers

Drivers

- **China's increasing need for energy sources that have less environmental impact and help improve air quality**
- **National R&D policies**
 - **Support for demonstrations of solar energy**
- **National policies emphasizing renewable energy and reduced pollution**
 - **Ability of solar electricity to substitute for coal**

Barriers

- **Building codes and regulations for electric utility connections to buildings**



An Economic Development Strategy for TBNA and TEDA

- **Become an R&D and manufacturing center for 2nd and 3rd generation solar electric systems**
- **Focus initially on the global export market**
- **Eventually expand to include the domestic Chinese market as it develops**



Action Plan: Develop State-of-the-Art R&D Capacity

- **Start with local capacity**
- **Develop relationships with leading research groups worldwide**
- **Aim to build state-of-the-art R&D on thin-film and nanoscale solar electricity technologies**



Action Plan: Build Up Manufacturing Capacity

- **Reach out to emerging 2nd and 3rd generation solar manufacturers**
- **Seek to attract to TBNA those manufacturers that best match TBNA and TEDA's developing R&D capabilities**



Action Plan: Establish Capacity for Commercialization

- **Draw best practices from U.S. states and municipalities with successful solar and other clean technology initiatives**
- **Review local building codes and electric utility regulations**
- **Consider revising these codes and regulations to encourage the use of solar electricity**
- **Take a leadership position in implementing environmental safeguards to differentiate TBNA's solar firms**

A Regional Path to Prosperity

- **Define the local context through critical problems and issues—this meeting will address:**
 - **New business models**
 - **Energy and environmental quality**
 - **Governance**
 - **Workforce education and training**
- **Make use of and build upon local capacities**
 - **University, government, private R&D**
 - **Manufacturing base**
 - **Local and regional organizations, institutions**
- **Include emerging technologies *that fit into this local context* in regional development plans**

Some Questions for Discussion

- **How might the structure of the regional economy change as the 21st Century progresses?**
 - **Growth areas? Balance? Goods vs. Services?**
- **How can we educate and train our workforce for these (uncertain) changes?**
- **How can we work together to make best use of local and regional resources (human, physical, institutional)?**