# Looking to the Future: Text-Analytics for Evidence-based Foresight

## Overview of TechMining-driven Future-oriented Technology Analyses (FTA)

Alan Porter
Search Technology

# Agenda

1. Future-oriented Technology Analysis (FTA)

2. Tech Emergence Indicators

3. Forecast Innovation Pathways (FIP)

# Overview:
# Future-oriented Technology Analysis (FTA)

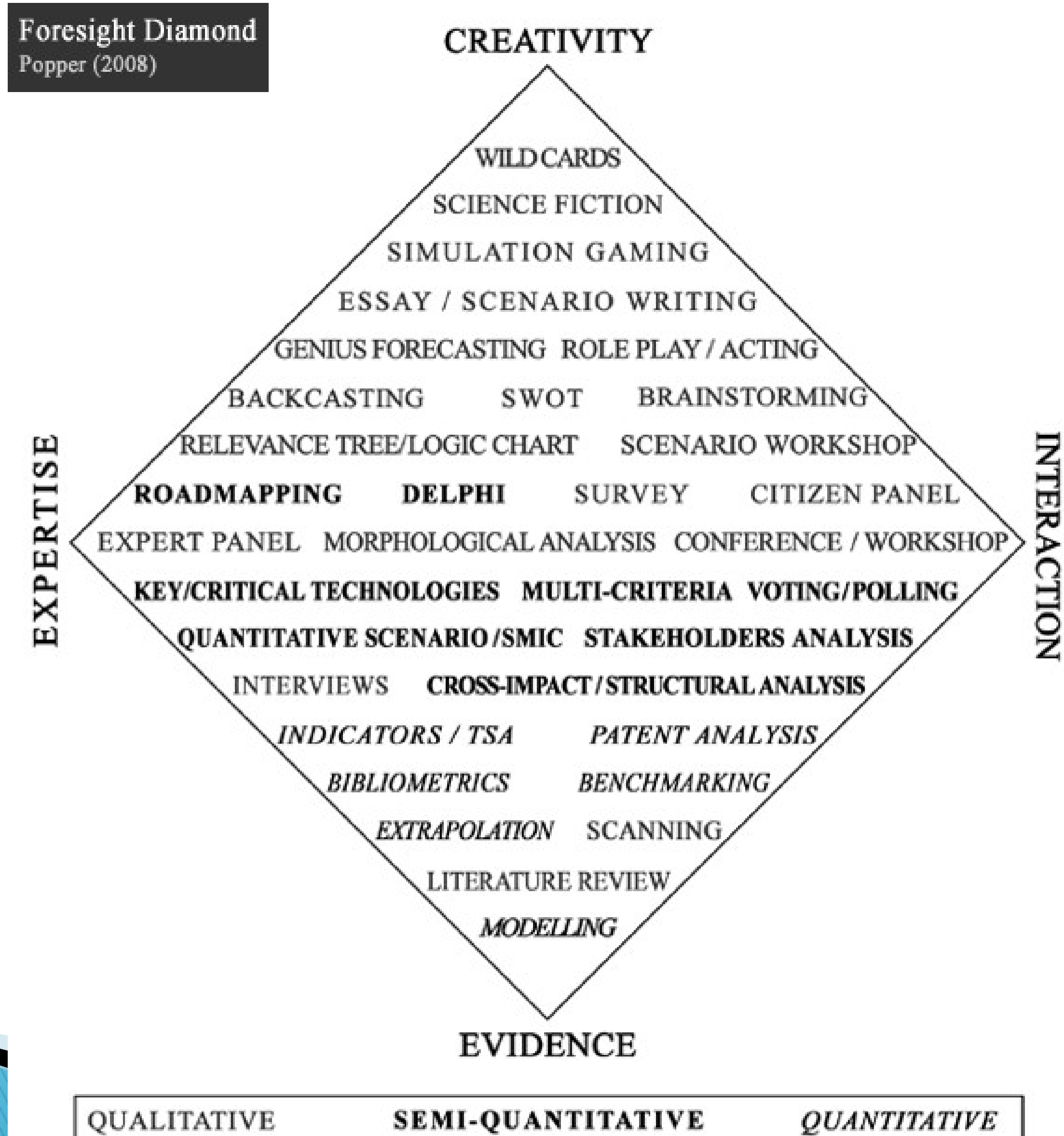
- Initiative to explore new FTA methods (2001 on)
  - Variants including: Tech Forecasting, Technology Assessment, Tech Foresight, …
  - 2 collective papers
  - European interest

- FTA Conferences –
  - IPTS, Seville, 2004, 2006, 2008, 2011,
  - EC, Brussels, 2014, 2018

# FTA: Changing…increasing need to take into account:

- Changing nature of “technological change” – increasingly **science-based** innovation (e.g., bio, nano)
- **Broadening concerns** (e.g., competitiveness, climate)
- **Opportunities to exploit diverse information resources with the aid of AI tools**
- Deal with **discontinuous advances** and radical innovation

# Classic FTA Methods



# FTA Types

| ISSUES | DIMENSION | STATE VALUES | | | |
|---|---|---|---|---|---|
| Content | Motivation | Extrapolative | Normative | | |
| | Drivers | Science (Research) | Technology (Development) | Innovation | Context |
| | Scope | Single Topic or Technology | Multiple Technologies | Wide-ranging Planning | |
| | Locus | Institution | Sector | Nation/ Region | Global |
| | Degree of Uncertainty | Prediction (quite certain) | Forecast (estimable risk) | Foresight (highly uncertain) | Indeterminant (unknown) |
| | Time Horizon | Short (1-2 year) | Mid-range (3-10 year) | Long (15+ years) | |
| | Purpose | Informational | Action-oriented | | |
| Process | Target Users | Few; knowledgeable | Diverse | | |
| | Participation | Narrow mix, closed process | Intermediate | Diverse mix, representative process | |
| | Study Duration | Day(s) | Month(s) | Year(s) | |

# Fit Methods to FTA Types to Achieve Goals: "Ten Commandments"

1. Focus on the triad of Data, Theory & Methods to exploit the data, knowledgeably & appropriately
2. Time available for a study constrains what methods will work
3. Use multiple methods
4. Blend quantitative + qualitative methods [e.g., empirical + expert opinion]
5. Integrate distinct methodological contributions + multiple human judgments
6. Assess FTA quality
7. Devise an explicit path to impact decision-making
8. Formulate an explicit communication plan, taking advantage of electronic media as suitable
9. Be prepared; some methods require TRAINING
10. RESEARCH on FTA methods needs support.

# Agenda

1. Future-oriented Technology Analysis (FTA)
2. Tech Emergence Indicators
3. Forecast Innovation Pathways (FIP)

# 4 Tech Emergence Criteria

Drawing on IARPA FUSE & Rotolo et al., What is an emerging technology? (2015) – seek 4 attributes:

- Term Novelty
- Term Persistence
- Term Growth
- Research Community

Not just "what's new?"

- Our formulation – 3 base + 7 active = 10 periods (e.g., years) of data
- Set of thresholds to surmount

# Tech Emergence: Payoffs → R&D Intel; Competitiveness/National Security Intel; Open Innovation; Forecasting

1) Identify '**hot topics**' in a tech domain [apt to be future targets of opportunity]
2) Identify cutting edge R&D **players [organizations, countries, and/or individuals]** (based on their emergent topic activity)
3) Spotlight R&D **publications or patents** rich in hot topic content
4) **Compare tech domains** on their extent of emergence

# Top COVID-19-related Research Emergent Topics [first half, 2020]

| Emergent Topic Groups | Records | 1949–2019 | 2020 (thru July 1) |
|---|---|---|---|
| Intensive Care Unit (ICU) | 1414 | 1.6% | 3.9% |
| Personal protective equipment | 1409 | 2.2% | 3.5% |
| Symptoms (e.g., fever) | 1364 | 2.2% | 3.3% |
| Patient Care Teaming | 1464 | 3.3% | 2.9% |
| Computerized Tomography (CT) | 984 | 0.7% | 2.9% |
| C–reactive protein (e.g., D–dimer) | 820 | 1.1% | 2.5% |
| Angiotensin–converting enzyme 2 (ACE2) | 950 | 1.3% | 2.0% |
| Diabetes | 797 | 0.4% | 2.5% |
| Hydroxycholoroquine (HCQ) | 736 | 0.2% | 2.4% |

# High Emergence Players (**Countries**) Nanotechnology Case

| Country | # Records | | Times Cited -- Mean | | Emergence Scores | |
|---|---|---|---|---|---|---|
| | 1991-2000 | 2006-2015 | 1991-2000 | 2006-2015 | 1991-2000 | 2006-2015 |
| **China** | 9760 | 287807 | 19 | 13 | 121 | 1201 |
| USA | 43706 | 248979 | 54 | 22 | 177 | 485 |
| So. Korea | 3709 | 70985 | 21 | 13 | 76 | 416 |
| India | 2376 | 66054 | 25 | 10 | 63 | 396 |
| **Iran** | 49 | 30963 | 11 | 8 | 4 | 331 |

# Agenda

1. Future-oriented Technology Analysis (FTA)
2. Tech Emergence Indicators
3. Forecast Innovation Pathways (FIP)

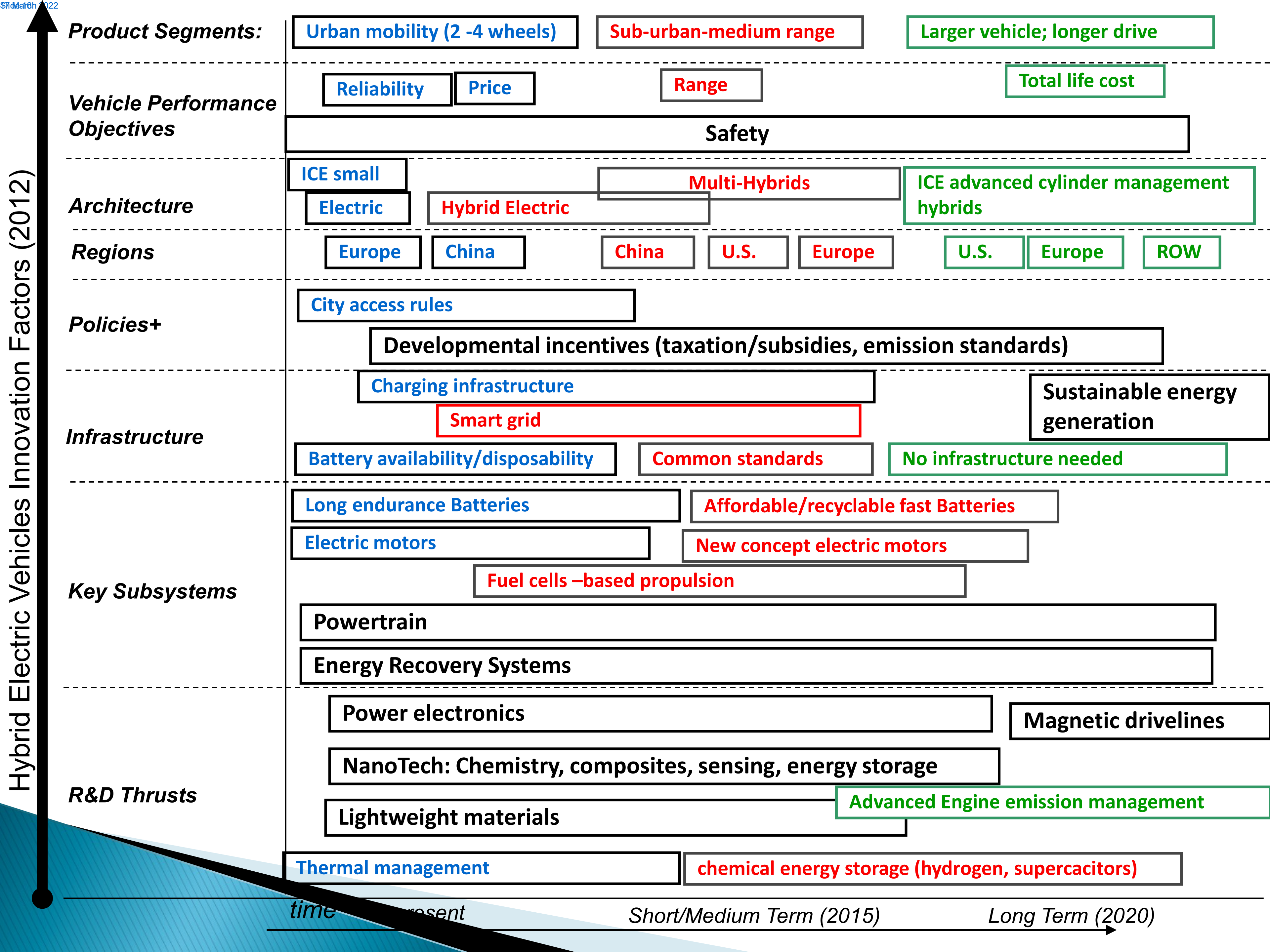
# Forecasting Innovation Pathways (FIP)

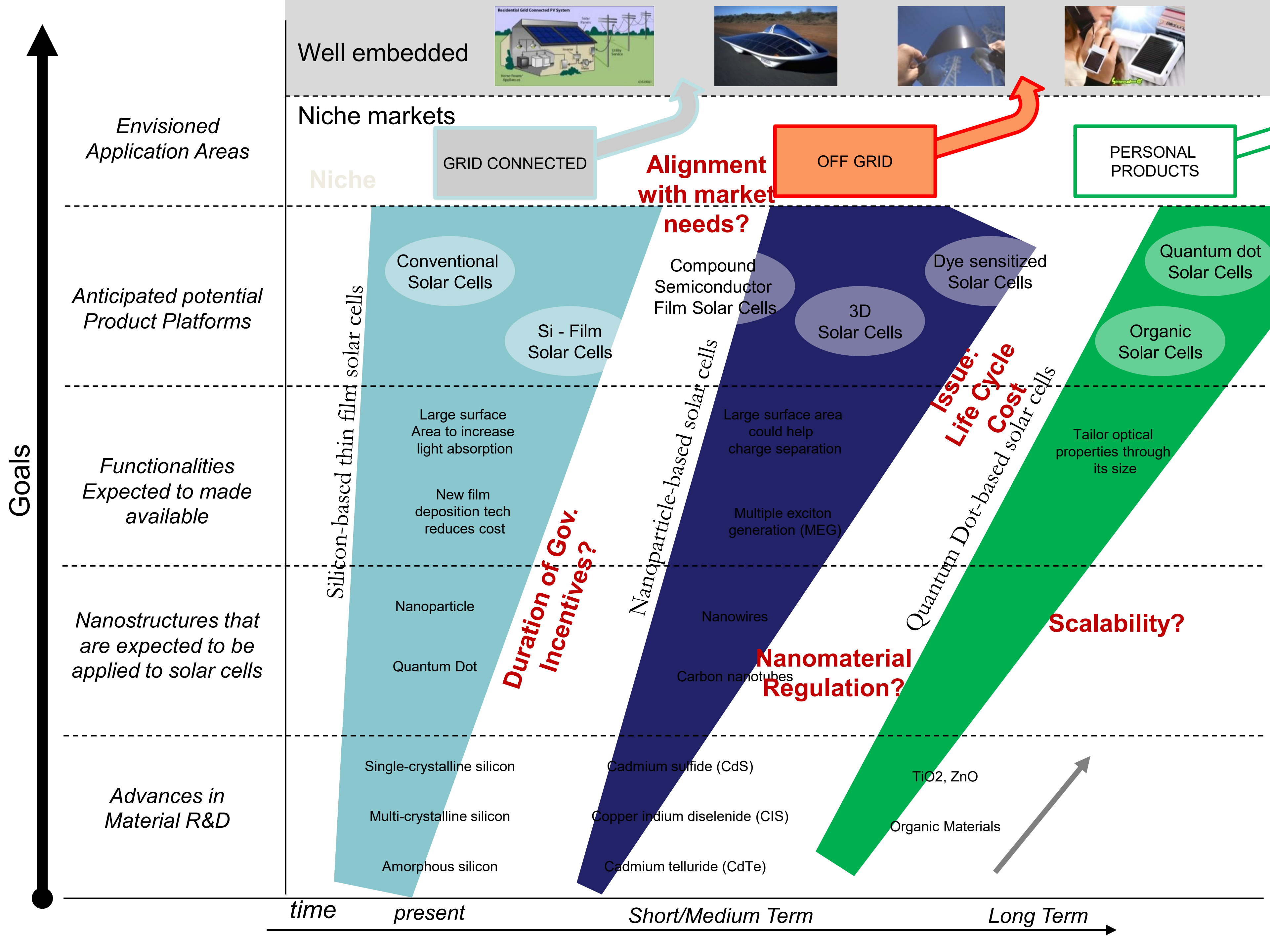
1. Combine multiple methods to forecast promising paths to applications of an emerging technology
2. Employ
   - empirical Tech Mining +
   - Informal, interactive expert opinion methods

# 10 Steps (non-linear!) to Forecast Innovation Pathways (FIP)

| | |
|---|---|
| **STAGE ONE**<br>Understand the NEST and its TDS (Technology Delivery System) | **Step A**: Characterize the technology's nature |
| | **Step B**: Model the TDS |
| **STAGE TWO**<br>Tech Mine | **Step C**: Profile R&D |
| | **Step D**: Profile innovation actors & activities |
| | **Step E**: Determine potential applications |
| | **Step J**: Engage experts |
| **STAGE THREE**<br>Forecast likely innovation paths | **Step F**: Lay out alternative innovation pathways |
| | **Step G**: Explore innovation components |
| | **Step H**: Perform Technology Assessment |
| | **Step J**: Engage experts |
| **STAGE FOUR**<br>Synthesize & report | **Step I**: Synthesize and Report |

Search Technology, 2013


Hybrid Electric Vehicles Innovation Factors (2012)
Product Segments:
Urban mobility (2 -4 wheels)
Sub-urban-medium range
Larger vehicle; longer drive
Vehicle Performance Objectives
Reliability
Price
Range
Total life cost
Safety
Architecture
ICE small
Electric
Hybrid Electric
Multi-Hybrids
ICE advanced cylinder management hybrids
Regions
Europe
China
China
U.S.
Europe
U.S.
Europe
ROW
Policies+
City access rules
Developmental incentives (taxation/subsidies, emission standards)
Infrastructure
Charging infrastructure
Smart grid
Sustainable energy generation
Battery availability/disposability
Common standards
No infrastructure needed
Key Subsystems
Long endurance Batteries
Affordable/recyclable fast Batteries
Electric motors
New concept electric motors
Fuel cells –based propulsion
Powertrain
Energy Recovery Systems
R&D Thrusts
Power electronics
Magnetic drivelines
NanoTech: Chemistry, composites, sensing, energy storage
Lightweight materials
Advanced Engine emission management
Thermal management
chemical energy storage (hydrogen, supercacitors)
time
Short/Medium Term (2015)
Long Term (2020)



Goals
Well embedded
Niche markets
Niche
GRID CONNECTED
OFF GRID
PERSONAL PRODUCTS
Alignment with market needs?
Envisioned Application Areas
Anticipated potential Product Platforms
Functionalities Expected to made available
Nanostructures that are expected to be applied to solar cells
Advances in Material R&D
Silicon-based thin film solar cells
Conventional Solar Cells
Si - Film Solar Cells
Large surface Area to increase light absorption
New film deposition tech reduces cost
Nanoparticle
Quantum Dot
Single-crystalline silicon
Multi-crystalline silicon
Amorphous silicon
Duration of Gov. Incentives?
Nanoparticle-based solar cells
Compound Semiconductor Film Solar Cells
3D Solar Cells
Dye sensitized Solar Cells
Large surface area could help charge separation
Multiple exciton generation (MEG)
Nanowires
Carbon nanotubes
Nanomaterial Regulation?
Cadmium sulfide (CdS)
Copper indium diselenide (CIS)
Cadmium telluride (CdTe)
Issue: Life Cycle Cost
Quantum Dot-based solar cells
Quantum dot Solar Cells
Organic Solar Cells
Tailor optical properties through its size
Scalability?
TiO2, ZnO
Organic Materials
time
present
Short/Medium Term
Long Term

# A Few of 100 Papers Citing FIP (Robinson et al.)

- 2021 Discovering technology opportunities based on the linkage between technology and business areas: matching patents and trademarks
- 2021 Understanding the Trends in Blockchain Domain Through an Unsupervised Systematic Patent Analysis
- 2021 Engineered Nanomaterials: The Challenges and Opportunities for Nanomedicines
- 2020 Mapping technological trajectories and exploring knowledge sources: A case study of 3D printing technologies
- 2019 Identifying and monitoring the development trends of emerging technologies using patent analysis and Twitter data mining: The case of perovskite solar cell technology
- 2019 Innovation pathways in additive manufacturing: Methods for tracing emerging and branching paths from rapid prototyping to alternative applications
- 2019 Extending technological trajectories to latest technological changes by overcoming time lags

# Resources


- Porter, A.L., (2010), Technology Foresight: Types and Methods, *International Journal of Foresight and Innovation Policy*, 6 (1/2/3), 36-45.

- Robinson, D.K.R., Huang, L., Guo, Y., and Porter, A.L. (2013), Forecasting Innovation Pathways for New and Emerging Science & Technologies, *Technological Forecasting & Social Change*, 80 (2), 267-285.

- *Technological Forecasting & Social Change*: Special Section on Forecasting Technical Emergence (16 papers), with open access to 8 of those through September 14, 2019 at https://vpinstitute.org/academic-portal/tech-emergence-contest/tech-emergence-bibliography/.