# Overview
# Evaluation Methods for R&D Programs

Presented to the NSTDA Evaluation Team
July 25, 2008
Bangkok, Thailand
Gretchen Jordan, Sandia National Laboratories, U.S.A.

A Guide Prepared for
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy (EERE)

Principal Author: Rosalie T. Ruegg, TIA Consulting, Inc., ruegg@ec.rr.com

# Topics:

- Why evaluate?

- Why multiple methods?

- Determining your specific evaluation needs

- Methods overview

- About individual methods
  - description
  - uses
  - strengths
  - limitations
  - examples

- Wrap-up: summary/questions/discussion

# Why Evaluate?

- ## To guide program management & strategy

  - how is the program performing?
  - are there performance problems?
  - are there problems with operational efficiency?
  - are adjustments needed?

- ## For accountability

  - is the program doing what it was intended to do?
  - is it worth continued support?
  - at the same level; at a reduced level?
  - are fundamental design changes needed?

# Why Multiple Methods?

- to answer the different questions stakeholders ask

- to provide alternative perspectives

- to provide multiple lines of evidence of results

# Past vs. Future Evaluation in EERE

- EERE in the past has relied primarily on peer review for evaluation of its programs

- But recently EERE has introduced its managers to a variety of methods

- It encourages its program managers to consider broadening their use of evaluation as needed.

# Developing an Evaluation Strategy

Determine your specific evaluation needs, asking:
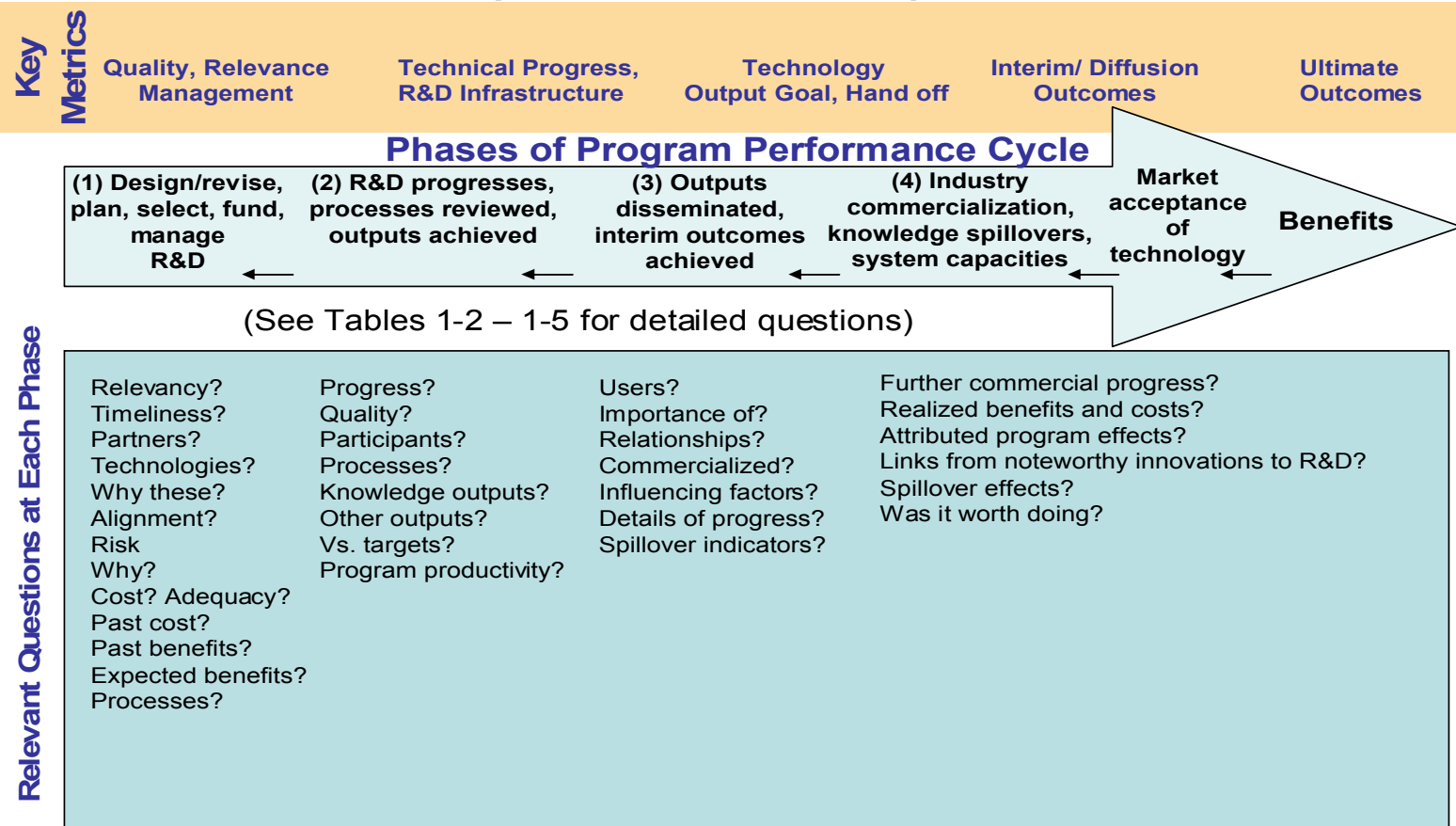
"WHO needs to know WHAT and WHEN"

- WHO:   you, other program staff, senior managers, OMB, Congress, other stakeholders
- WHAT:  information about progress, how to improve, outcomes, impacts, need for changes in strategy
- WHEN:  in advance, short-term, intermediate term, long term

# Developing an Evaluation Strategy:  A Roadmap to help you get started

- Step-by-step process outlined in booklet

- Start with a logic model for your program

- Use tables to locate appropriate method(s)

# Start with Program Logic Model

**Secretary Bodman's and Other Performance Assessment Questions Span the Performance Spectrum**

**Key Metrics**

| Quality, Relevance Management | Technical Progress, R&D Infrastructure | Technology Output Goal, Hand off | Interim/ Diffusion Outcomes | Ultimate Outcomes |
|---|---|---|---|---|

**Phases of Program Performance Cycle**

| (1) Design/revise, plan, select, fund, manage R&D | (2) R&D progresses, processes reviewed, outputs achieved | (3) Outputs disseminated, interim outcomes achieved | (4) Industry commercialization, knowledge spillovers, system capacities | Market acceptance of technology | Benefits |
|---|---|---|---|---|---|

(See Tables 1-2 – 1-5 for detailed questions)

**Relevant Questions at Each Phase**

| | | | |
|---|---|---|---|
| Relevancy? | Progress? | Users? | Further commercial progress? |
| Timeliness? | Quality? | Importance of? | Realized benefits and costs? |
| Partners? | Participants? | Relationships? | Attributed program effects? |
| Technologies? | Processes? | Commercialized? | Links from noteworthy innovations to R&D? |
| Why these? | Knowledge outputs? | Influencing factors? | Spillover effects? |
| Alignment? | Other outputs? | Details of progress? | Was it worth doing? |
| Risk | Vs. targets? | Spillover indicators? | |
| Why? | Program productivity? | | |
| Cost? Adequacy? | | | |
| Past cost? | | | |
| Past benefits? | | | |
| Expected benefits? | | | |
| Processes? | | | |

[Source: Gretchen Jordan, SNL]

Revised 03/21/2006

8

# Evaluation Methods Provide Info Needed at the 4 Phases of the Performance Cycle

- Planning info
- Indicators of interim progress
- Depictions of relationships
- Creation & dissemination of knowledge
- Energy savings/provision, economic, environmental, security & other effects
- Spillover effects
- Comparative standing
- Overview—was it worth it?

# Directory of Methods

- Peer review/expert judgment--to assess qualitatively (usually informed by quantitative evidence) such things as:

  - research quality
  - researcher productivity
  - feasibility of goals
  - program success

- Monitoring/tracking activities, milestones & outputs

  - to provide short-term performance answers
  - to indicate need for strategic corrections
  - to help build databases for quantitative evaluation

# Directory of Methods, continued (p.2)

Methods focused on demonstrating knowledge creation & dissemination:

- ## Bibliometrics, including 3 distinct methods
  - counts & citation analysis of publications & patents
  - hotspot patent analysis
  - text data mining

- ## Network analysis
  - diagramming (knowledge-flow) connections among people & organizations

- ## Historical tracing
  - documenting linkages between R&D and **use** in downstream innovations

# Directory of Methods, continued (p.3)

## Methods focused on economic effects:

- ### Benefit-cost analysis
  - relates benefits and costs, providing measures of net benefits, benefit-to-cost ratio, and/or rate of return on investment; for public programs, usually includes private and social returns (including measurable spillover effects)

- ### Technology Commercialization Tracking
  - DOE's internal monitoring of technologies considered to be commercially successful, with assessment of their direct energy savings, & direct economic and environmental benefits

# Directory of Methods, continued (p.4)

Methods for describing programs, understanding program theory, answering specific questions, and making comparisons:

- ## Case study
  -  telling the stories of research; explaining the what, why, and how of research; exploring hypotheses for further exploration

- ## Survey
  -  asking people questions, coding responses, aggregating and analyzing data; using statistical, tabular, & graphical techniques to report results, show trends, rate customer satisfaction, generate performance measures, etc

- ## Benchmarking method
  -  comparing aspects of programs, institutions, regions, countries, or other entities with selected performance measures

# Directory of Methods, continued (p.5)

Cross-cutting:

Econometric methods—encompassing multiple mathematical & statistical techniques used to capture relationships between R&D investment and changing economic, technological, and social phenomena

Examples of Uses:

- to estimate market spillover benefits using a cost-function model
- to measure the impact on firm productivity of participating in government-funded research using a production-function model
- to extract more info with greater rigor from survey results

# Directory of Methods, continued (p.6)

**Multiple Methods for Spillover Analysis –** methods to capture effects external to the decision to undertake (invest in) an activity

"Research Spillovers" may encompass:

- **Knowledge spillovers** — knowledge captured by others without paying

- **Market spillovers** (consumer & producer surplus) — increased uncompensated value in new & improved goods & services

- **Network spillovers** — increased value from existing goods and services due to complementarities provided by new technologies

# Spillovers cause social returns to diverge from private returns



- **Pure Market Spillover**
- **Plus Pure Knowledge Spillover**
- **Plus Interaction of the Two**
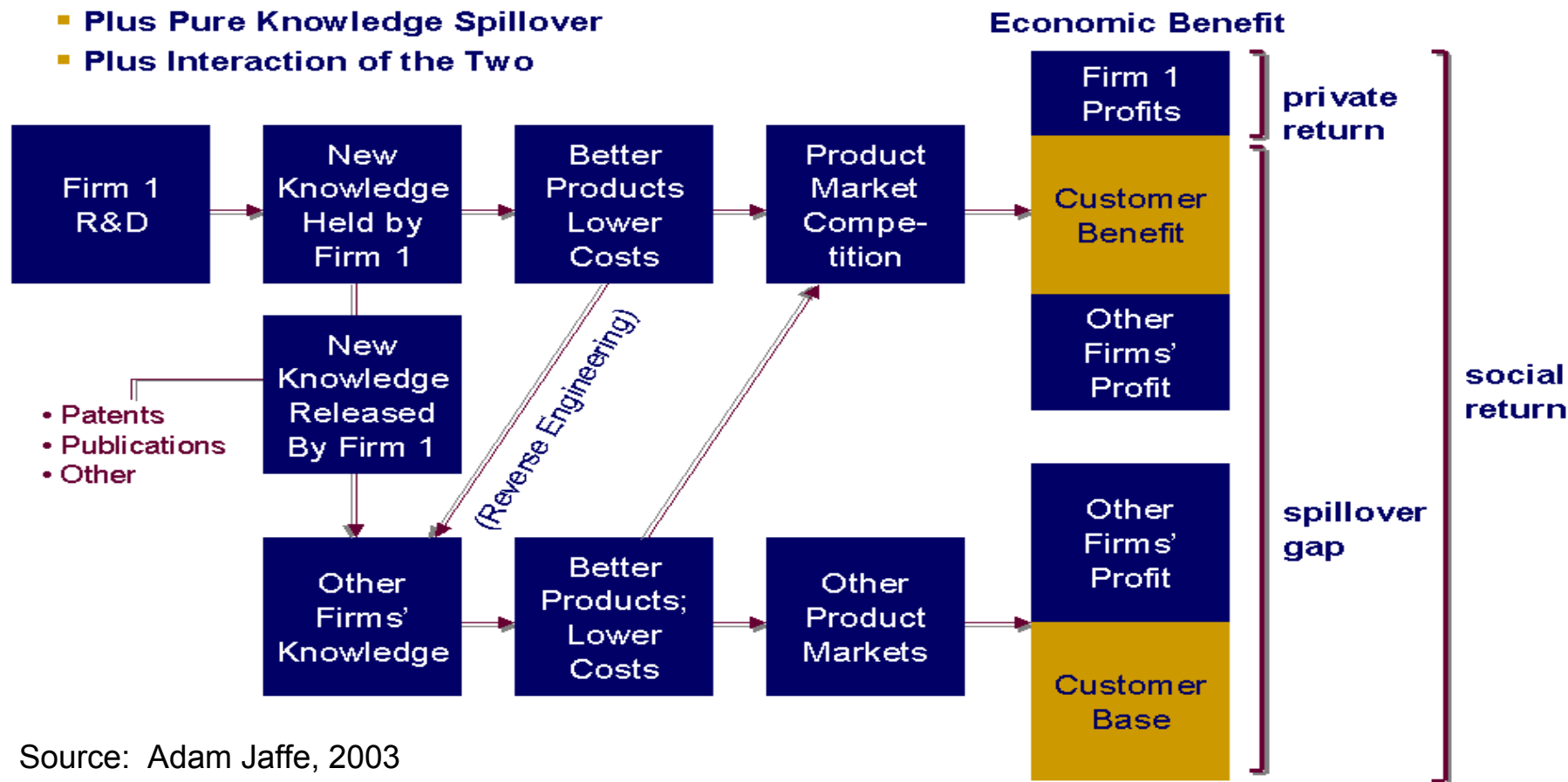
Source: Adam Jaffe, 2003

# More on Selected Methods

- Benefit-Cost Study

- Historical Tracing Study (combined with citation analysis)

# Benefit-Cost Studies

Benefit-cost studies quantify positive and negative effects of a project in monetary terms, and compares the resulting benefits and costs.
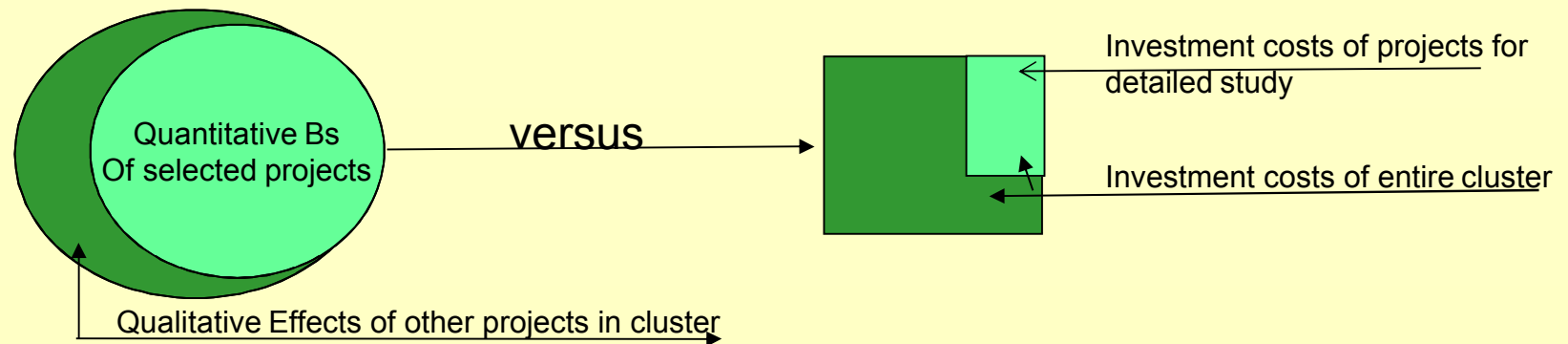
Uses:

- to demonstrate economic effectiveness of a program
- to guide R&D investment decisions (prospective)

Measures:

- Net present value or annual value dollars
- Benefit-to-cost ratio
- Rate of return on investment

# Benefit-Cost Studies, continued #1

- ## Applications:

  - to a single **applied** research project
  - to a cluster of related **applied** research projects

- Cluster Study:  compares benefits of several selected projects in a cluster to the entire cluster costs



Quantitative Bs
Of selected projects

versus

Investment costs of projects for detailed study

Investment costs of entire cluster

Qualitative Effects of other projects in cluster

# Benefit-Cost Studies, continued #2

Expected to account for:

- Additionality (i.e., benefits & cost with the project versus without the project)

- Different timing of benefits & costs

- Risk & uncertainty

- Interactions among projects (if cluster study)

- Distinction between social and private benefits

# Historical Tracing Method

- Forward tracing from R&D to downstream outcomes

R&D — Innovation 1, Innovation 2, Innovation 3, Innovation 4
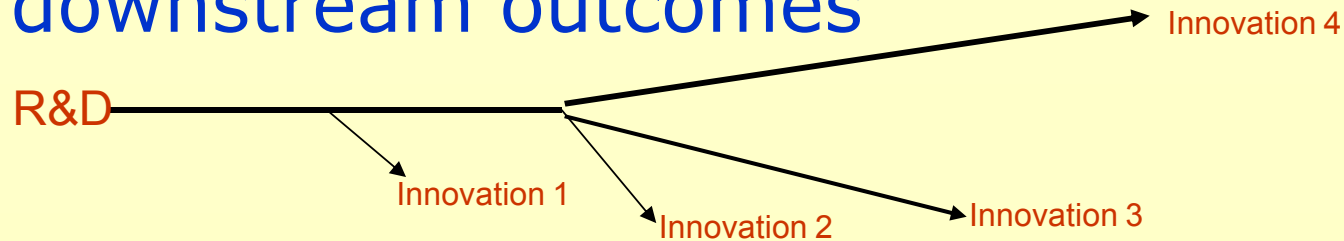
- Backward tracing from a selected outcome to upstream R&D
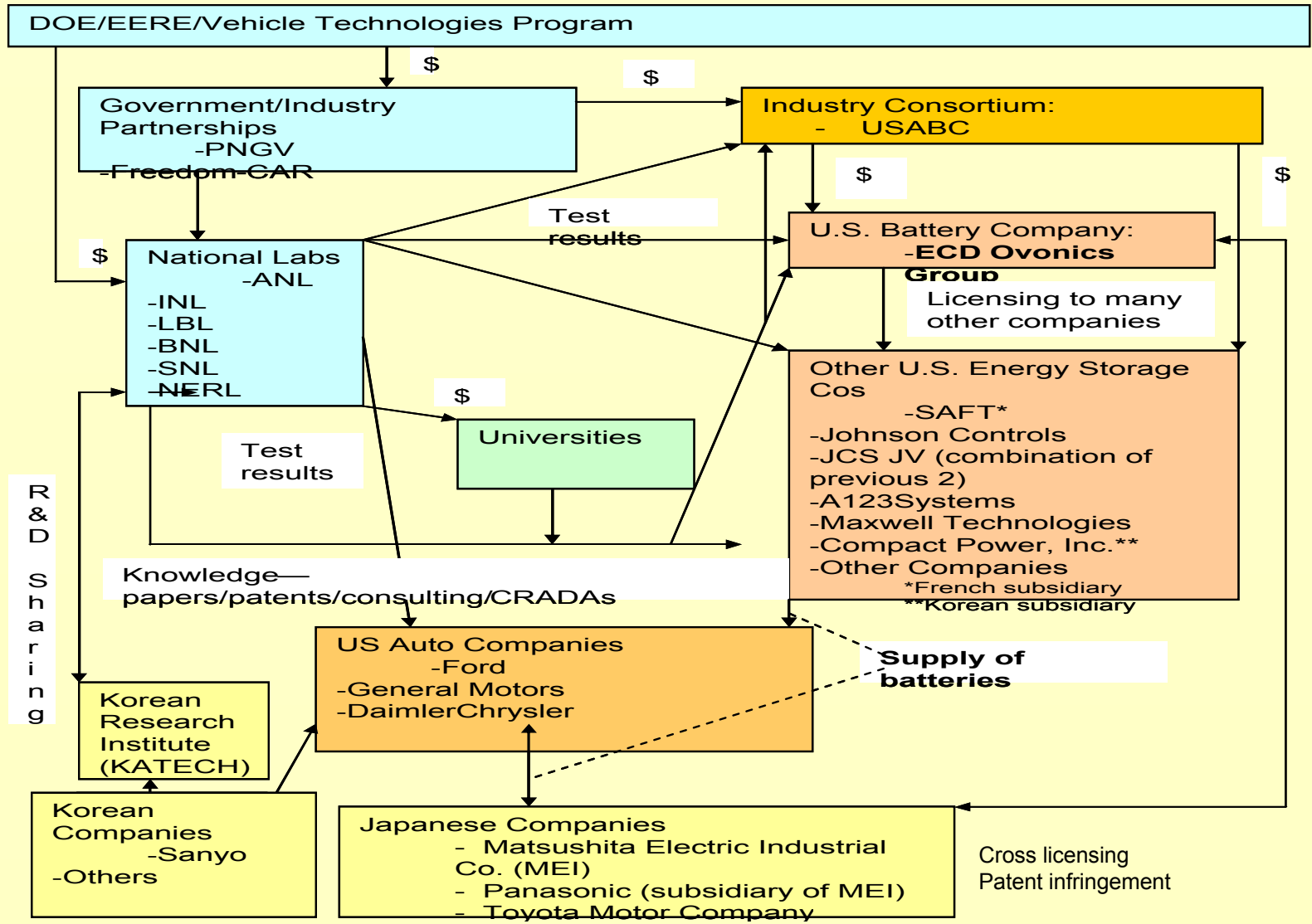
R&D ? ? ? ← Target Innovation
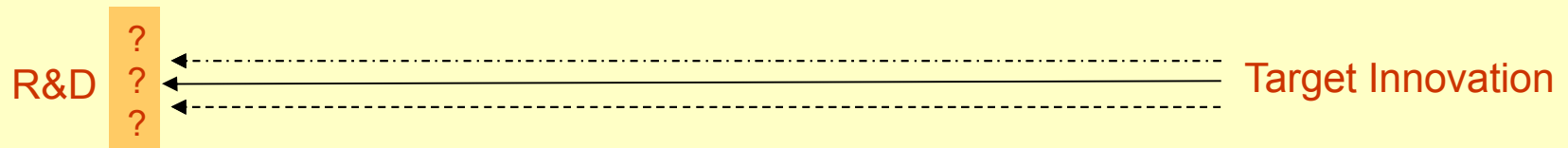
# Historical Tracing Method, continued #1

- Uses:

  - Document paths linking R&D with downstream products and processes

  - Show the evolutionary processes by which R&D leads to innovation

  - Compare (qualitatively) a demonstrably valuable innovation against a research program shown to underpin the innovation

- Techniques:

  - Expert interview to identify/understand key developments

  - Document review

  - Combined with patent citation analysis

# Example: Sample Findings from Report Linking FCVT Battery R&D to HEV/PHEV/EV

- Documented linkages from DOE R&D funding to the invention and development of 3 of the most prominent energy storage technologies for HEV/PHEV/EV – NiMH & Li-Ion batteries & ultracapacitors

- Showed that highly cited HEV battery/ultracapacitor patents cite earlier DOE-funded patents forming a foundation for these technologies

- Demonstrated real-world relevance of DOE's R&D in energy storage to hybrid and electric vehicles

**Linkages Identified By Experts**

DOE/EERE/Vehicle Technologies Program

$

$

Government/Industry Partnerships
-PNGV
-Freedom-CAR

Industry Consortium:
- USABC

$

$

$

Test results

National Labs
-ANL
-INL
-LBL
-BNL
-SNL
-NERL

U.S. Battery Company:
-**ECD Ovonics Group**
Licensing to many other companies

$

Universities

Other U.S. Energy Storage Cos
-SAFT*
-Johnson Controls
-JCS JV (combination of previous 2)
-A123Systems
-Maxwell Technologies
-Compact Power, Inc.**
-Other Companies
*French subsidiary
**Korean subsidiary

Test results

R&D Sharing

Knowledge—papers/patents/consulting/CRADAs

US Auto Companies
-Ford
-General Motors
-DaimlerChrysler

**Supply of batteries**

Korean Research Institute (KATECH)

Korean Companies
-Sanyo
-Others

Japanese Companies
- Matsushita Electric Industrial Co. (MEI)
- Panasonic (subsidiary of MEI)
- Toyota Motor Company

Cross licensing
Patent infringement

24

# Linkages Identified by Citation Analysis

**Steps in developing patent data sources:**

- Step 1.  Identify the total population of US patents linked to DOE-funded research

- Step 2.  Identify the downstream population of patents related to HEV/PHEV/EV batteries and ultracapacitors

- Step 3.  Determine the downstream HEV/PHEV/EV battery/ultracapacitor patents identified in Step 2 that were also found in the DOE population identified in Step 1

- Step 4.  Identify the number of DOE-funded patents identified in Step 1 that were **cited** by any of the HEV/PHEV/EV battery/ultracapacitor patents identified in Step 2, e.g., patents for component technologies such as electrolytes

- Step 5. Determine how many times the 222 DOE patents that were cited by HEV battery/ultracapacitor patents were cited by these patents

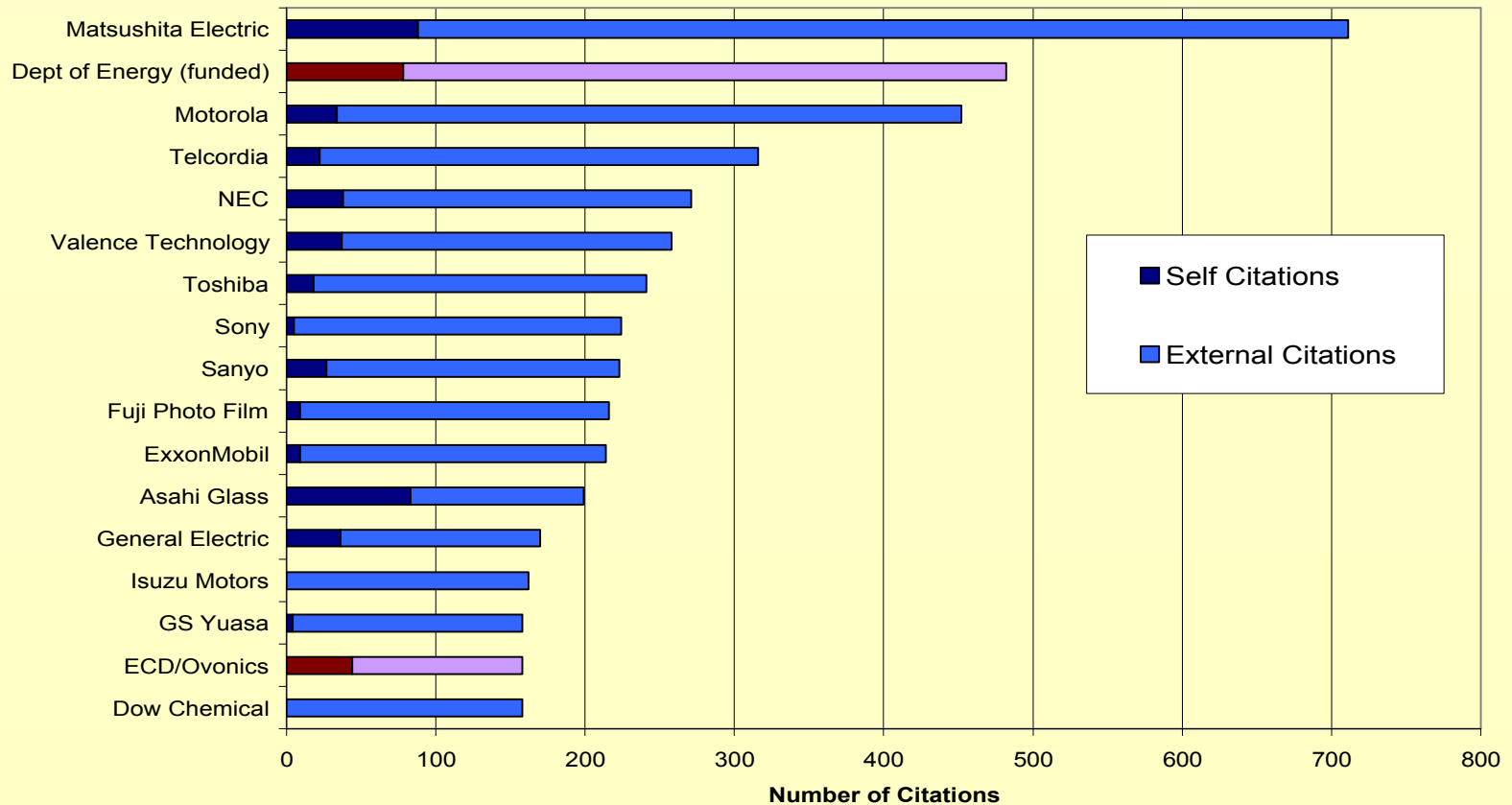First Generation Patent Tree for US5348822, Issued to Ovonic Battery Company in 1994
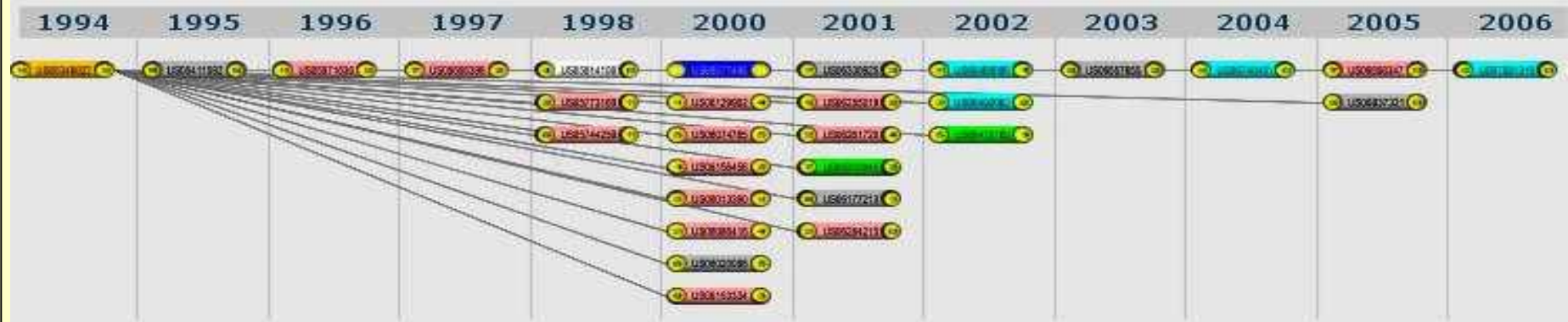
# Second Generation Patent Tree for US 5348822, Issued to Ovonic Battery Company in 1994
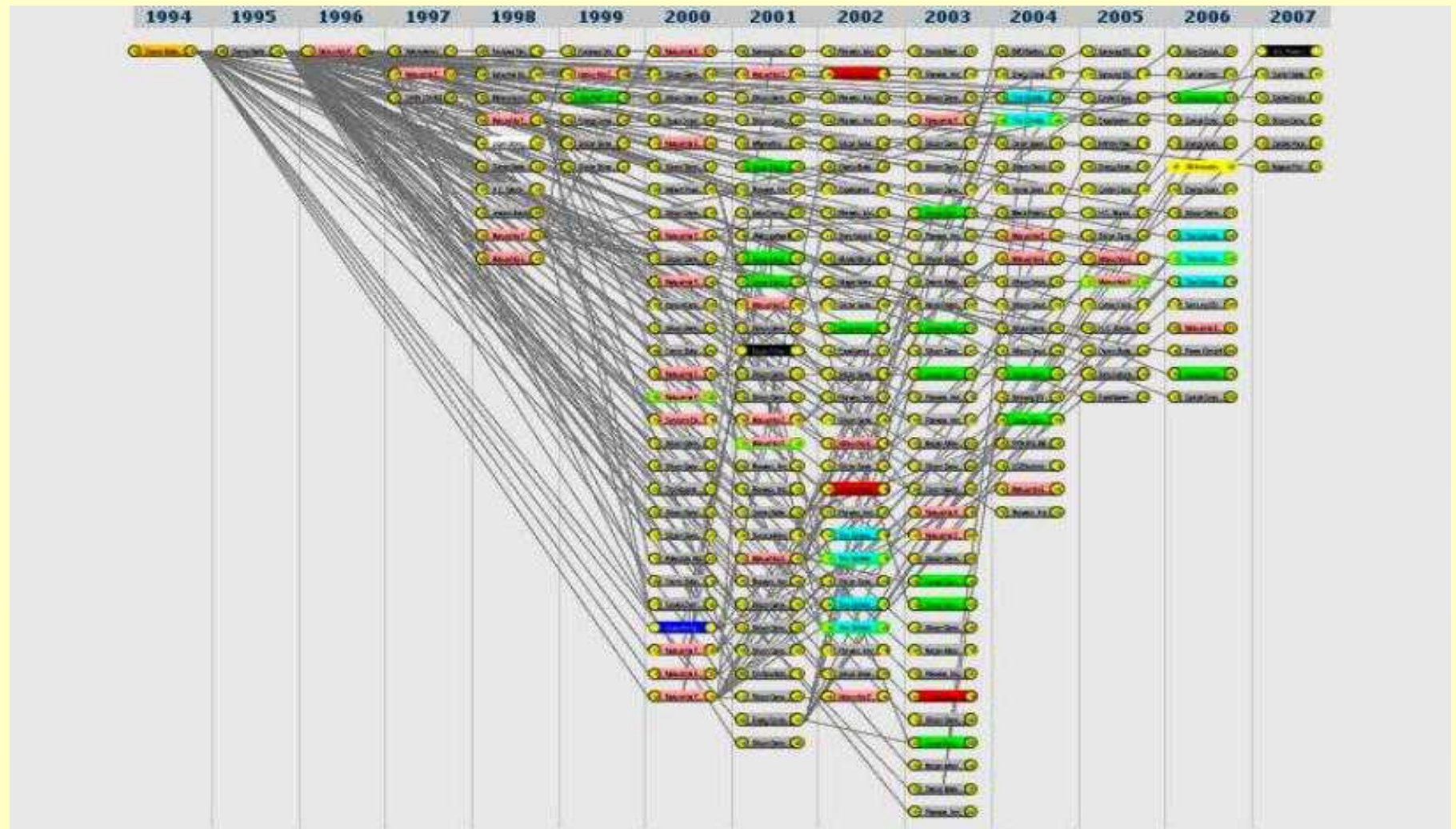
# Historical Tracing Example, continued



Figure 6-3.  Organizations whose patents are cited most frequently
by HEV Battery/Ultracapacitor Patents

# Wrap-up

- Summary

- Questions

- Discussion

View and download the booklet at
http://www1.eere.energy.gov/ba/pba/pdfs/evaluation_methods_r_and_d.pdf.