Program Review


Bell Telephone Laboratory, ca. 1955

J. M. Morabito, Chairman

March, 2009

Presentation Objectives

- Present a framework, proven in other high-technology industries, for assessing the opportunities, required resources, and complex, interrelated bottlenecks facing the solar industry.
- Demonstrate how this framework can be applied to maximize solar industry value creation and leverage DOE’s investments in solar development.
- Support the transition of our peer-review conversation from project details and individual efforts to the “big picture” of where the solar industry may be headed and what DOE’s best role may be.

Moving from the question of whether

we are doing the projects right

to a question of whether

we are doing the right projects

Alcatel·Lucent

Overview of the DOE Solar Energy Technology Program

- The near-term goal of the DOE program is to drive the cost of solar electricity to grid parity in terms of LCOE.
- Support platform and critical R&D that has long-term significance and transfer these to industry.
- Innovation is a key focus to achieve grid parity—the core of innovation is cross-functional integration.
- DOE can have a unique leadership role in the growth of the Solar Industry; i.e., Accelerate the activities and innovations that private industry would not do on its own.
- The Solar Industry has the potential to enter a “virtuous cycle” of lower cost, new technology and expanded markets.
- To reach its full potential, the Solar Industry requires close coordination between a number of public and private stakeholders; i.e. collaboration in critical industry issues including Federal Energy Policy.

Solar Industry Structural Evolution

- Industrial strategy is about structural evolution and market positioning.
  - DOE has a critical role in the creation of a successful strategy for the U.S. Solar Industry.
  - DOE must anticipate the Solar Industry's likely evolution and support a program to secure a sustainable U.S. competitive advantage.
- Ultimately, the Solar Industry will dwarf both Semiconductor and Flat Panel Display industries, but the Solar Industry can benefit and learn from these industries' characteristics:
  - Supporting structures for long-term growth, sustained profitability, & collective response to environmental, regulatory and other challenges
  - Global supply chains linked by industry-wide technology roadmaps, industry & environmental standards, manufacturing diagnostics, & other collective dependencies that accelerate technology transfer, reduce cost, & facilitate innovation.

What is at Stake?

- DOE needs to explore, in collaboration with all **stake**holders, how best to nurture and develop a supportive & collaborative U.S. Solar Industry.
- Decisions made today will impact the efficiency, sustainability, & profitability of a Global Solar Industry over the next 10, 20, 50 years — as well as determine which countries will be its leaders, e.g. China, Japan, USA, Germany, Spain….

1-MW BIPV, Suntech HQ Building, Wuxi, China   Source: Suntech Power Co.

Alcatel·Lucent

VALUE MIGRATION

Economy	Economic Drivers	Infrastructure	Economic Indicators	Environmental Protection
Agrarian (before 1800)	Land and Crops	Dirt roads and couriers on horseback	Commodity prices	No
Industrial Revolution (1800-1900)	Cheap steel, coal, textiles	Railroads, shipping, telegraph, steam engine	Coal and pig iron production, cotton consumption, railroad operating income	No
Mass Production (1900-1980)	Cheap energy, especially oil	Highways, airports, telephones, broadcasting, electric power grid	Retail sales, auto sales, housing starts, industrial production, capacity utilization	Command and control development of strict federal regulations
Technology/ Information (after 1980)	Ever-cheaper semiconductors and photonics, R&D programs, rapid technology change, knowledge/ software, direct electronic access	Satellites, fiber optics, networks, wireless, distributed power Worldwide web/the internet	Book to bill ratio, computer sales, deflation in high tech prices, power value, high tech trade balance, employment in knowledge intensive industries	Pollution prevention, industrial ecology, international standards (ISO), renewable energy

VALUE MIGRATION (Cont'd.)

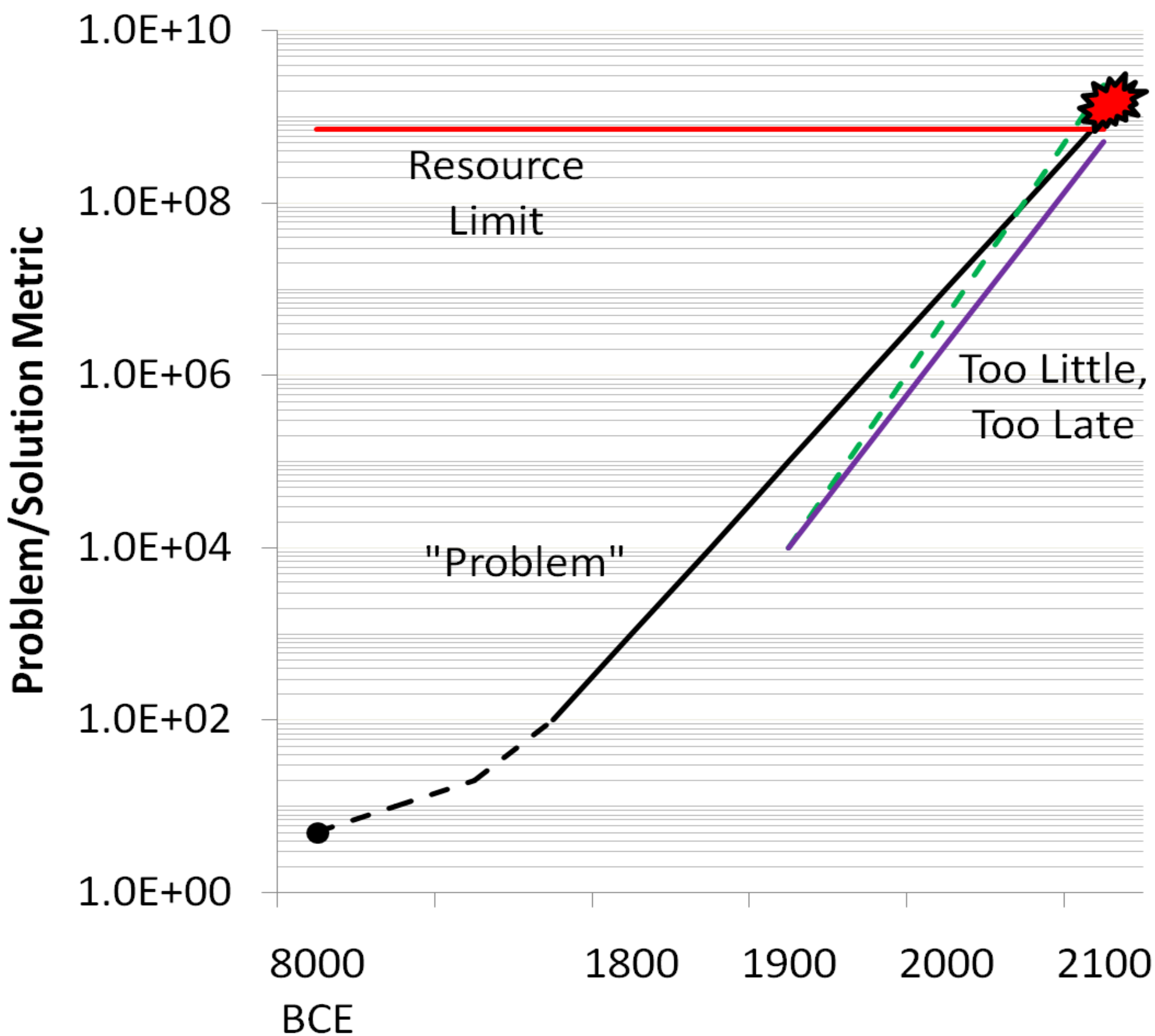
Economy	Economic Drivers	Infrastructure	Economic Indicators	Environmental Protection
• Sustainable Energy/ Information Intensity Era (after 2010) • Convergence of Electric Power and Information Technology	• Transition from EXTRACTION-based technology to SUSTAINABLE technology • The 7 C's	**Smart** • Smart Grid/ Energy Internet • Smart residential and commercial buildings for electricity generation and storage • Smart electric vehicles for transportation, electricity generation and storage	• Global Electrification • Global population stabilization • Employment in clean energy technologies • Efficient systems for utility grids, traffic management, food distribution, water conservation, and health care	• Sustainability • Air and water quality • Biodiversity • Forestation • Carbon Tax Carbon Trading • Feed-in tariffs • Renewable Portfolio Standards & Fuel Efficiency Standards (CAFE) • Transnational Agreements

Alcatel·Lucent

Energy Industry Economic Drivers

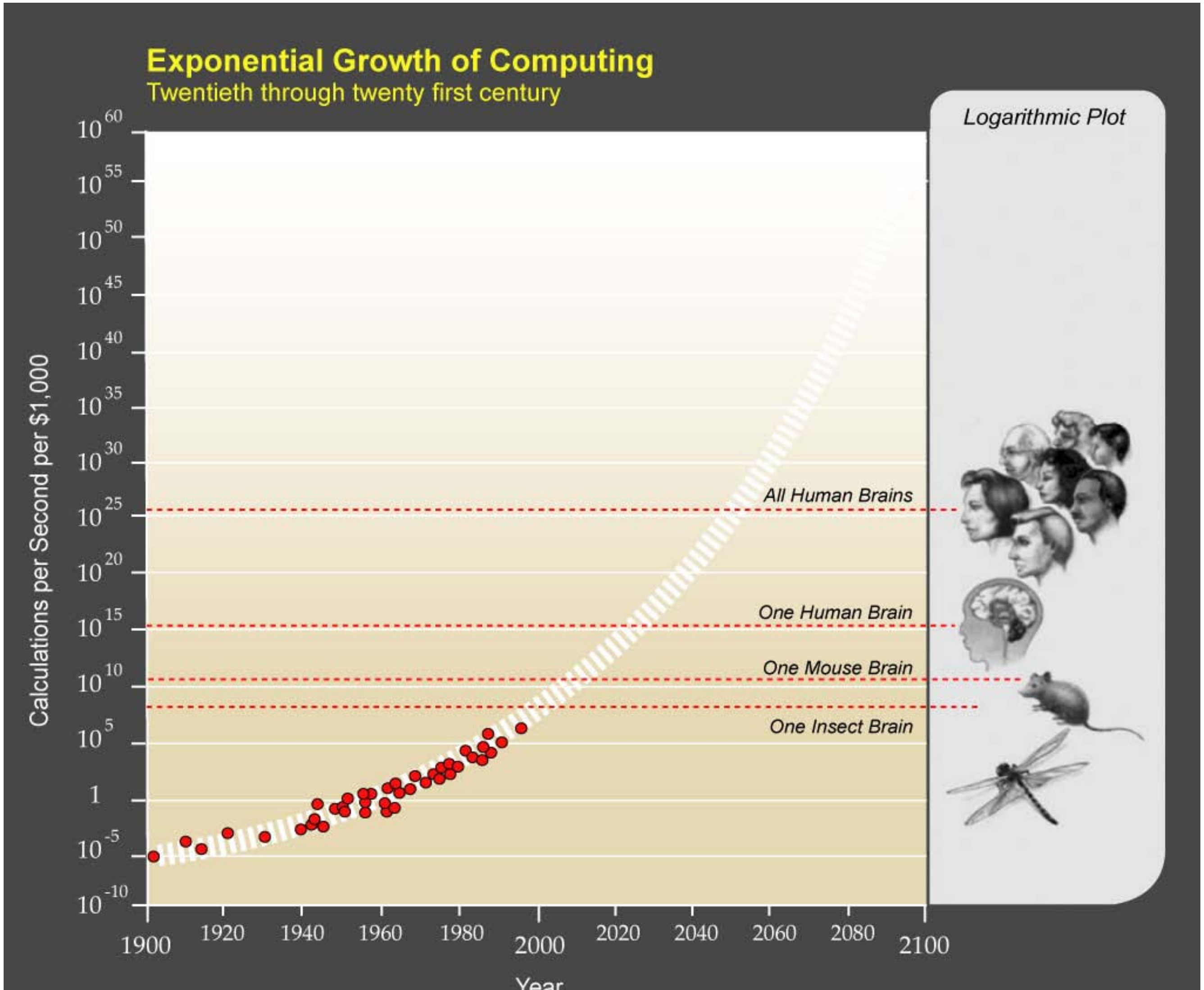
The 7 C's -

- Costs
- Capital
- Competition/ Cooperation
- China
- Consumers
- Climate/ Conservation/ Carrying Capacity
- Convergence



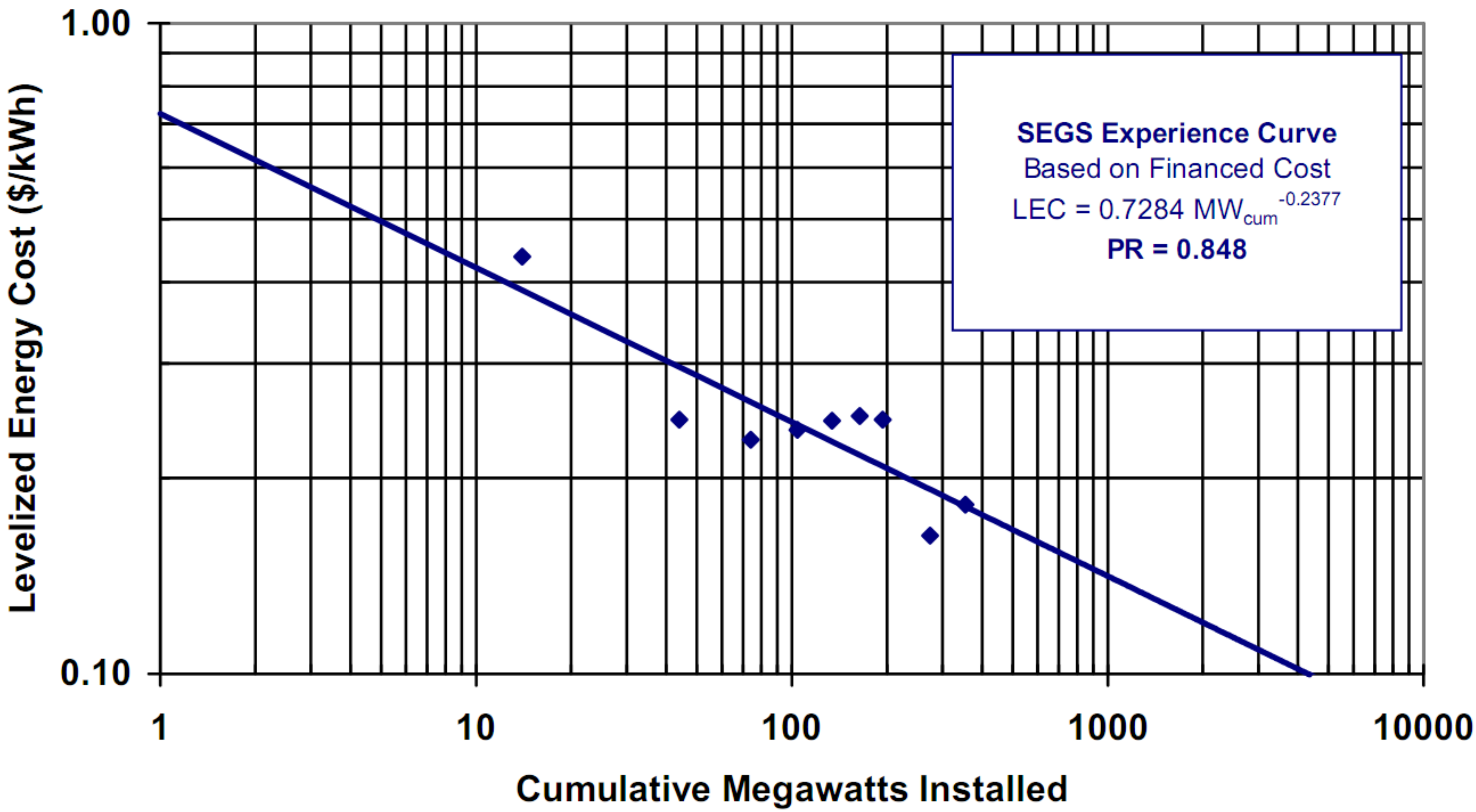
Alcatel·Lucent

Computational Learning Curve



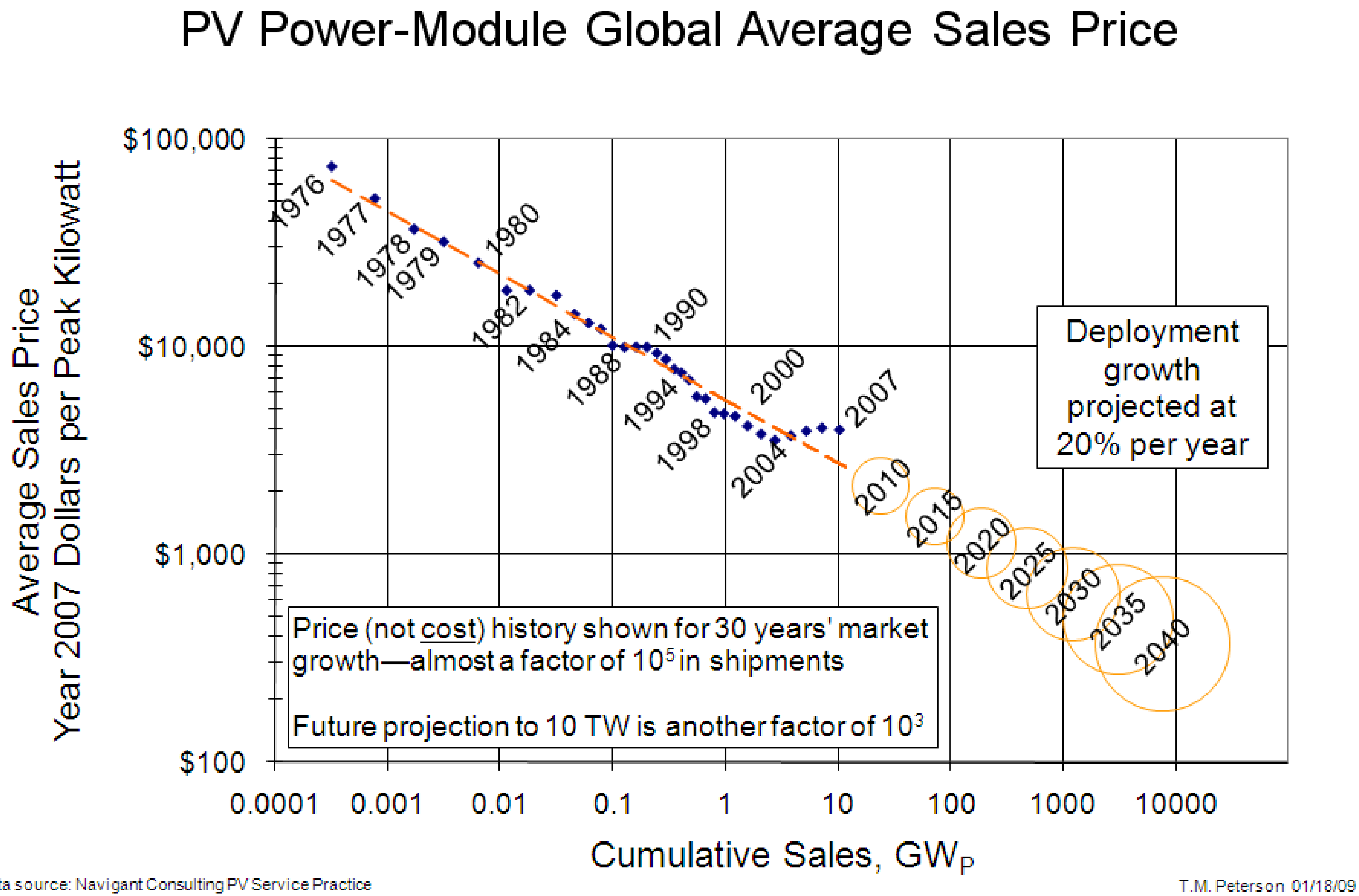
Source: R. Kurzweil, “The Singularity is Near”

Concentrating Solar Power Exponential Innovation



Source: H.W. Price & S. Carpenter, "The Potential for Low-Cost Concentrating Solar Power Systems"

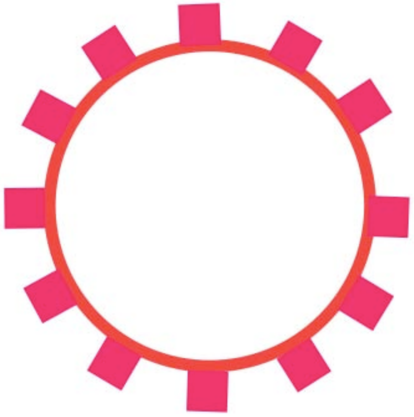
Another Example of Exponential Innovation Growth



Alcatel·Lucent

A Tool to Understand, Integrate and Evaluate

Think of the portfolio of project activities at the system level as an interconnected set of functions that reinforce each other. Examine and understand the linkages and interactions between elements that comprise the entirety of the Solar Industry development system.

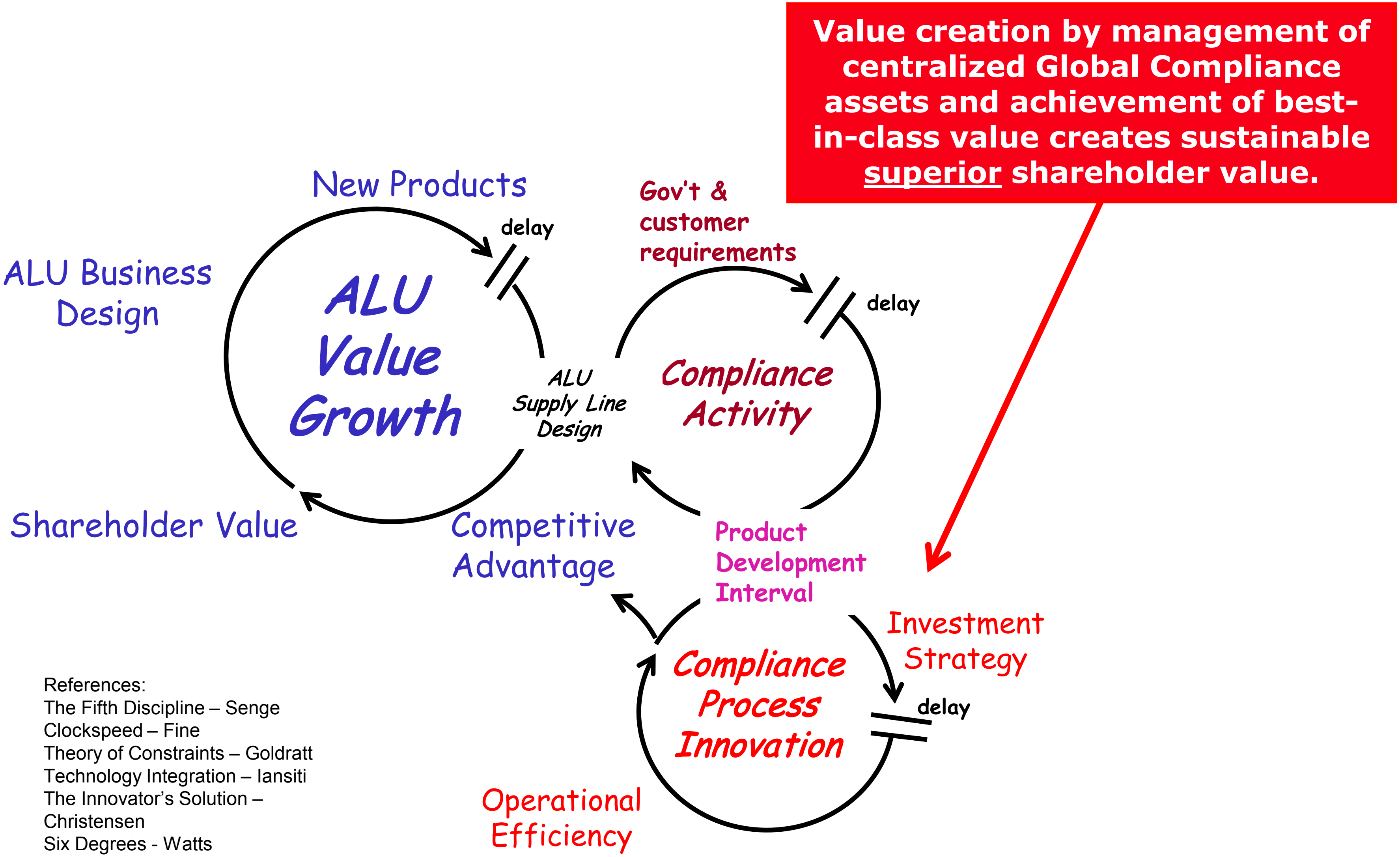


Systems Thinking

- Is any process of estimating or inferring how local policies, actions, or changes influences the state of the neighboring aspects.
- Systems thinking shows how events that are separated in distance and time can interact and how the rules of the system drive system behavior. Small catalytic events, especially ones that change the rules, can cause large changes in complex systems.
- **One goal of Systems Thinking is identifying "leverage" -- seeing where actions and changes lead to sustainable improvement.**
- **Cause and effects are not always closely related in time and space (resulting in "delays").**

Examples: Supply Chain Design, Program Management.

Systems Thinking (Senge Diagram) Representation of the Compliance Activity and its effect on Alcatel-Lucent Value Growth



References:
The Fifth Discipline – Senge
Clockspeed – Fine
Theory of Constraints – Goldratt
Technology Integration – Iansiti
The Innovator's Solution – Christensen
Six Degrees - Watts

Alcatel·Lucent

Senge Diagram —
Representation of System-Focused Solar Industry Development

The Solar Industry:

- Similar to automobile industry in ultimate scale—and hence, form
- Expect large companies designing complete systems from integrated subsystems delivered by a network of suppliers
- Can get "there" from "here" via a ***Global Solar Industry Value Creation*** process

The Energy Internet:

- Will evolve from today's grid
- Can use the Information Internet as model for development
- Key elements include standards for connecting consumers and producers to the network and availability of an infrastructure for transport and storage
- Can start with ***"Smart Grid" Infrastructure Development*** process

Senge Diagram — Representation of System-Focused Solar Industry Development

The Solar Industry:

- Similar to automobile industry in ultimate scale—and hence, form
- Expect large companies designing complete systems from integrated subsystems delivered by a network of suppliers
- Can get "there" from "here" via a *Global Solar Industry Value Creation* process

The Energy Internet:

- Will evolve from today's grid
- Can use the Information Internet as model for development
- Key elements include standards for connecting consumers and producers to the network and availability of an infrastructure for transport and storage
- Can start with *"Smart Grid" Infrastructure Development* process

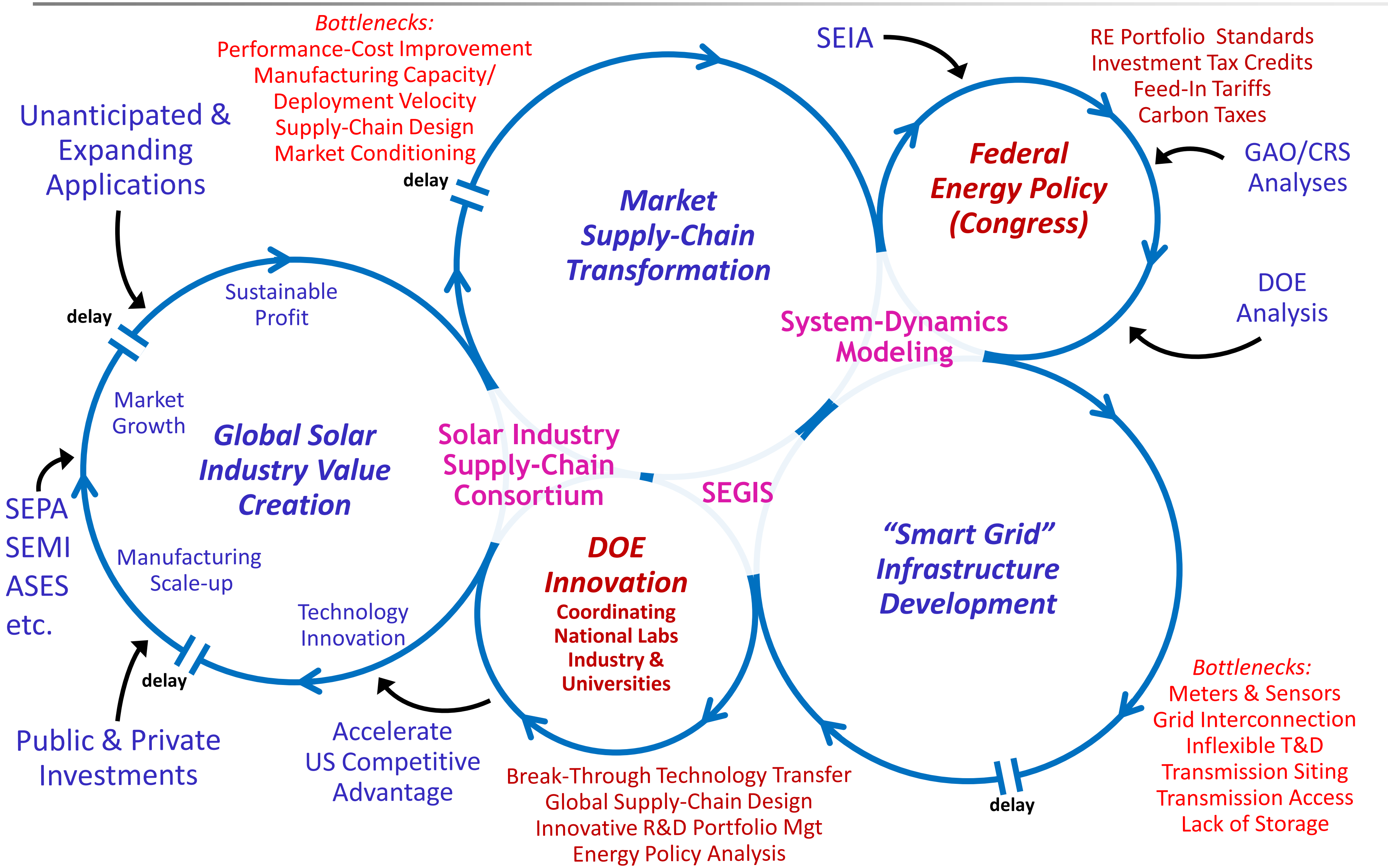
Global Solar Industry Value Creation

How do these relate?

"Smart Grid" Infrastructure Development

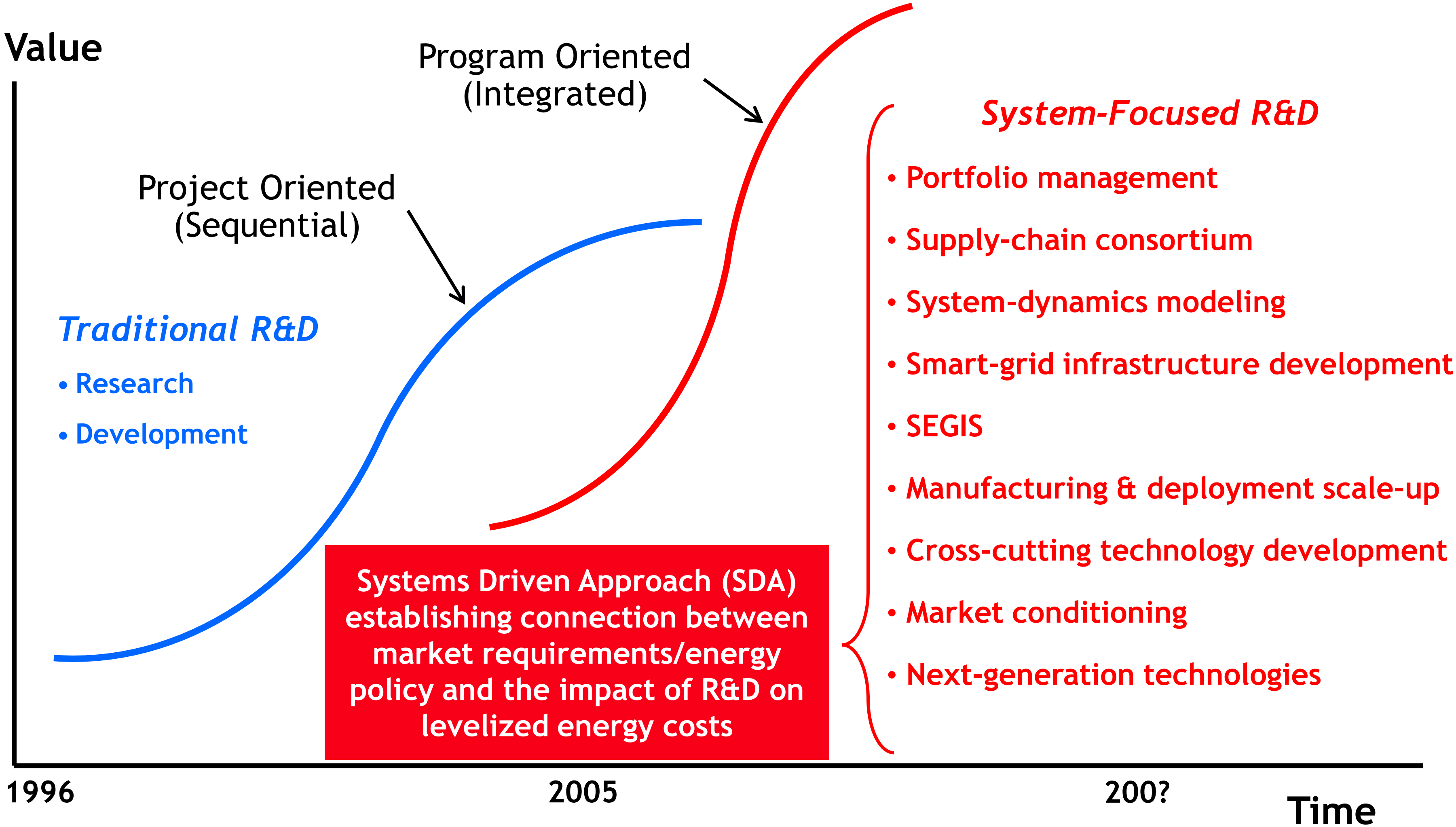
Alcatel·Lucent

Senge Diagram –
Representation of System-Focused Solar Industry Development



Alcatel·Lucent

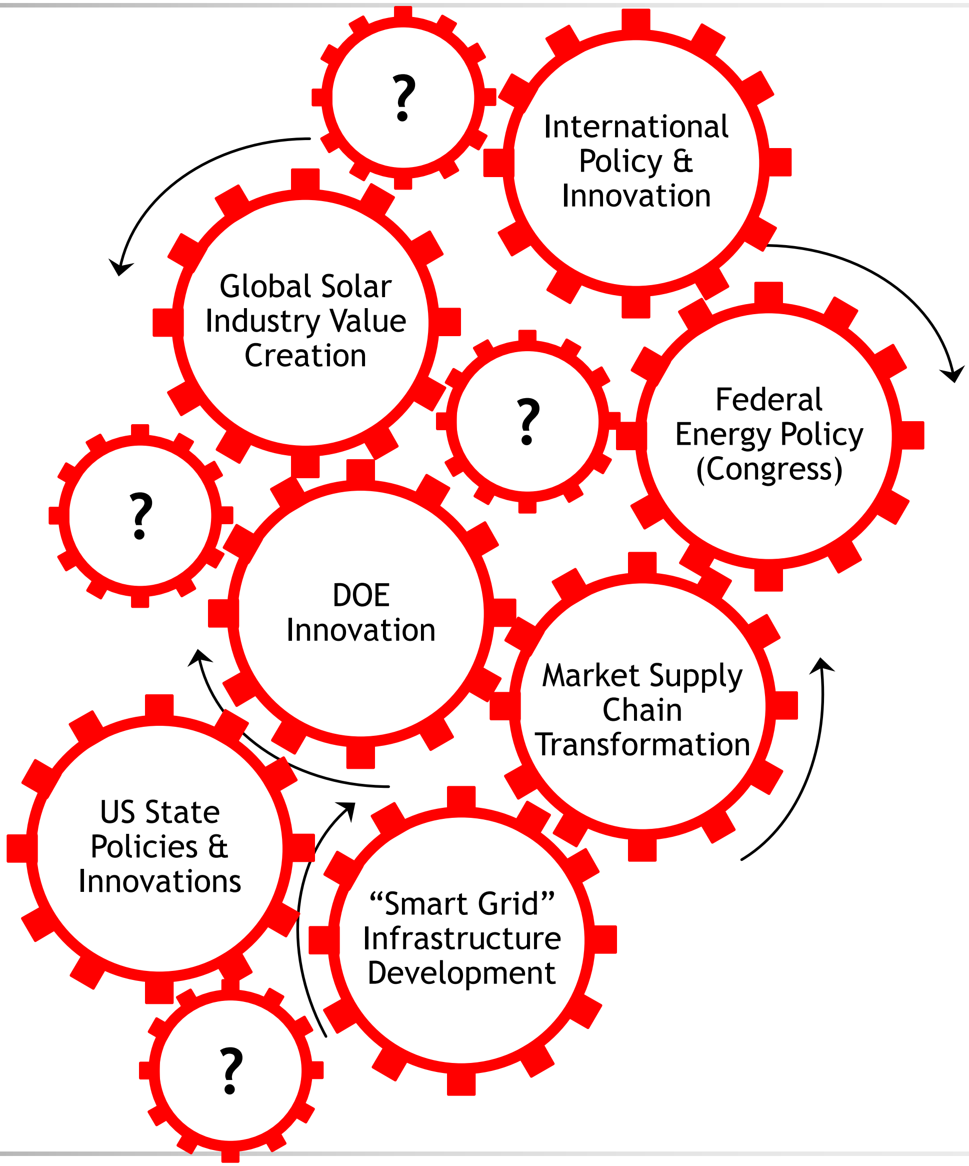
Solar System-Focused Integrated Innovation



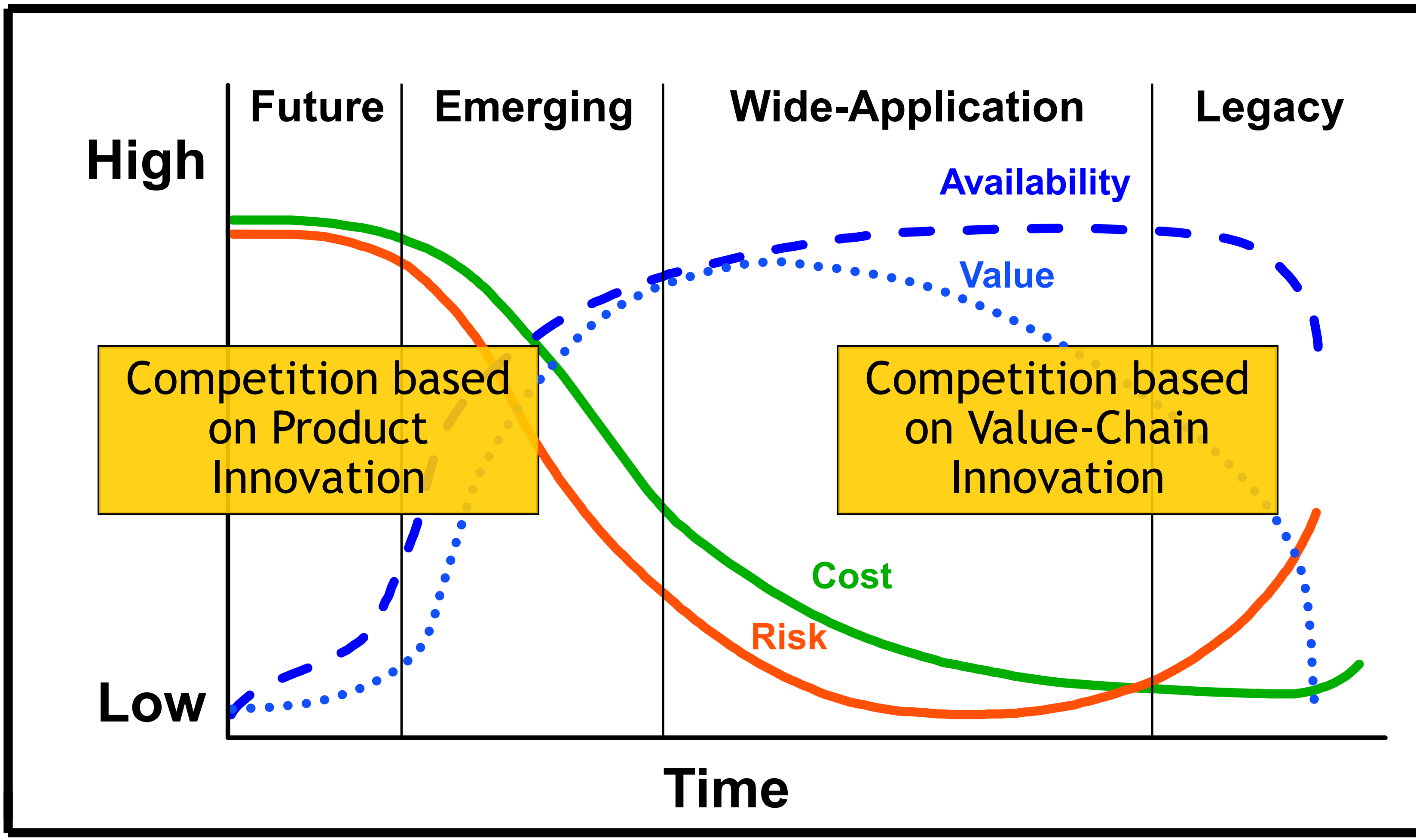
Alcatel·Lucent

Powering the Solar Innovation Engine

- Interconnected systems reinforce the innovation process
  - Positive Reinforcement spins the wheels faster!
- Feedback loops create virtuous cycles, e.g.:
  - Availability of components in the Solar Energy supply chain → innovations in integrated systems → higher volume → more demand for components
  - Promotion of standards in the Smart Grid → more products designed to the standards → higher utility of products that work together → greater incentive to adopt the standards

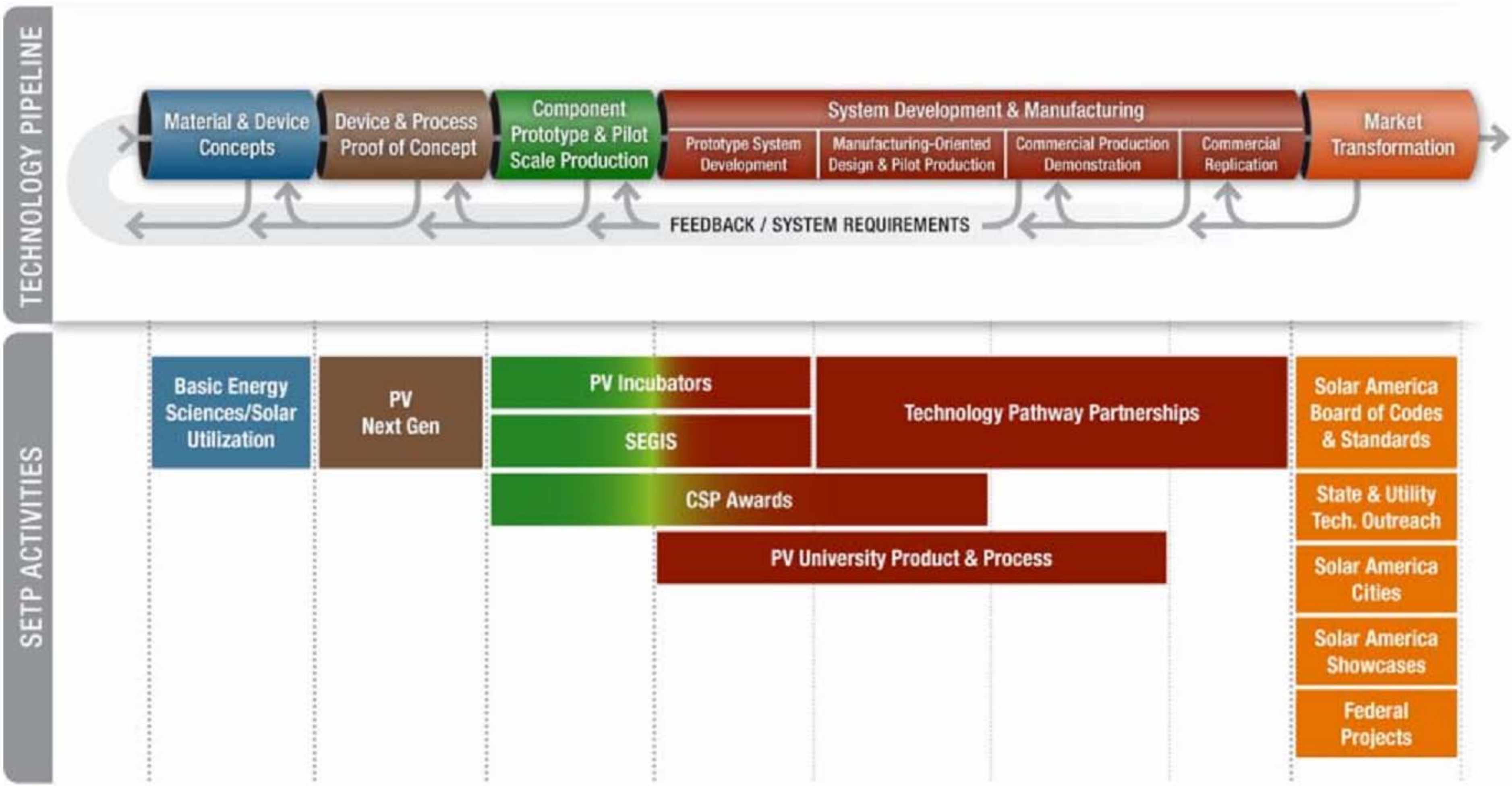


Technology Life Cycle Factors



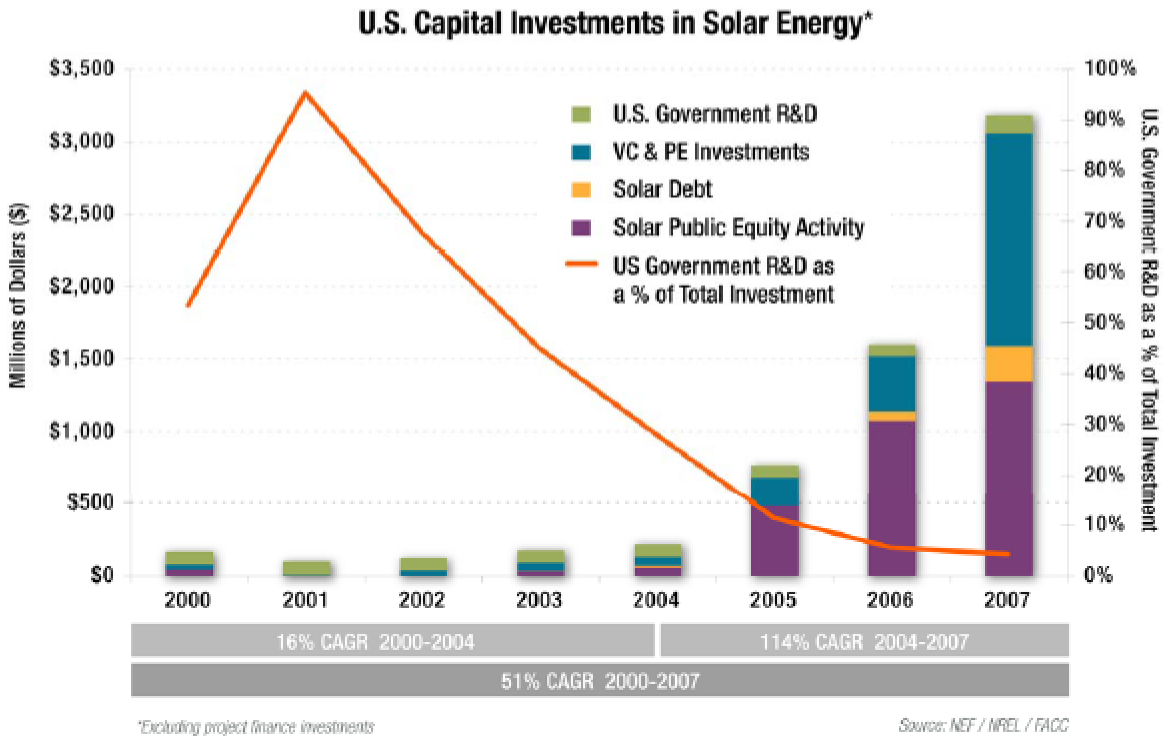
Alcatel·Lucent

SETP and DOE Innovation



Alcatel·Lucent

DOE's History of Investment in Solar Development



DOE Funding Advantages

1. Non-dilutive to company financing
2. Maximum IP ownership
3. Validates new technology for private investment
4. Preferential access to National Lab expertise and facilities

PV Supply Chain and Cross-Cutting Technologies

Transfer and optimize technologies specifically for the PV industry

- Attract new entrants as neutral vendors
- Target domestic leadership in value chain segments
- Mitigate risk across currently funded technologies
- Accelerate new products by developing "enabling" technologies

TOPIC AREAS

Module Components

- Flexible barrier or protective coatings
- Transparent conductors
- Contacts (high aspect ratio, printed, non-silver)

Non-Module Components

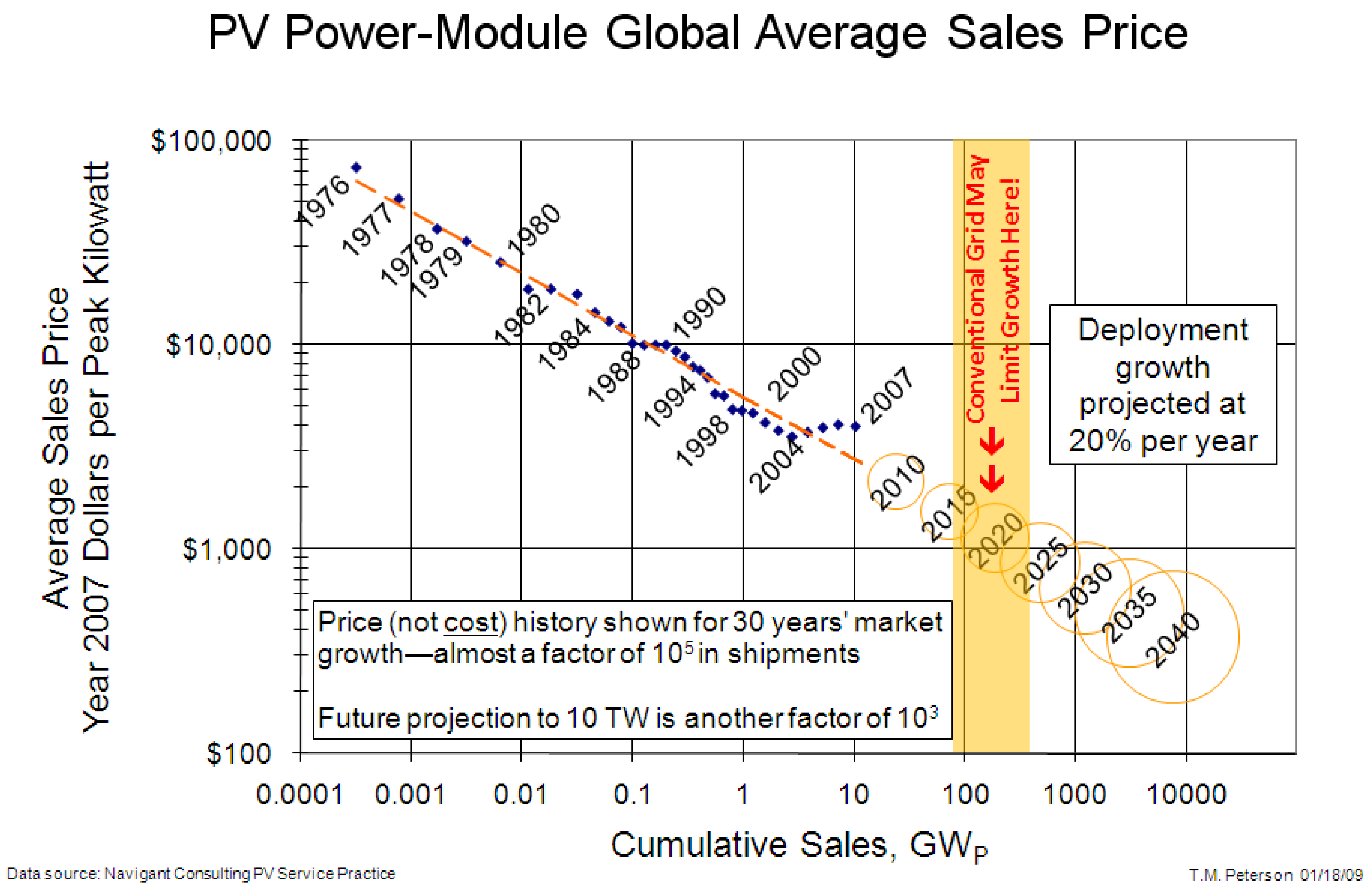
- Inverter components
- Trackers
- Streamlined balance of system solutions

Manufacturing

- CPV alignment
- Material flux measurement
- Fast optical characterization

- **Impact Factor = ($/W savings) X (project future sales volume)**
- **Value = Impact ($) / DOE funding**
- **Uniqueness - containing sufficient risk to necessitate DOE funding**
- **Feasibility – likelihood of success**

There are Three Major Bottlenecks for Global Solar Industry Value Creation



Alcatel·Lucent

Critical Investments for Research

- Market Awareness

  Combine knowledge of solar market needs and current market ecosystem with deep insights into associated technologies.

- Rapid Exploration

  Use platforms, processes and tools to test ideas rapidly [e.g. NREL's Solar Advisor Model (SAM) and PDIL, DOE EERE's Software: PV*SOL, Roanakh, PV-DesignPro, SNL's: CSP Components and Testing, System Development and Testing].

- System-Level Architecture & Design

  Build and maintain system models that are used throughout the development and deployment lifecycle.

- System-Focused Development / Robust Design / Taguchi Approach

  Support solar technology development with Robust Design processes to take advantage of efficiencies resulting from System Thinking.

Principles to Guide Decision Making in the DOE Energy Programs

- Is it Sustainable?
- Does it promote energy independence?
- Is it economically feasible?
  - If not, what would make it so?

What Is Sustainability ?

Key: Link <u>Economic Value</u> & <u>Carrying Capacity</u>

<u>Global Warming</u> (BEA, IPCC data)

Global Economic Output: GDP = $ 25.4 Tr. per yr

Global Carrying Capacity: ECC = 8.6 Tr. kg GWP

<u>Sustainable Productivity</u>: $3 per kg GWP

- **Eco-Efficiency: EE = Actual/Sustainable Prod.**

Each <u>Business</u> EE= 100% → <u>Economy</u> within ECC !

Is my Business Worth its Environmental Impact ?

Public/Gov't/Science: Stabilize Global Temp.!

<u>Business Challenge</u> - <u>Not Academic Exercise</u> !

- *Goal: <u>Green Marketing</u> …or <u>Sustainability</u> ?*

STM Example: TELECOM

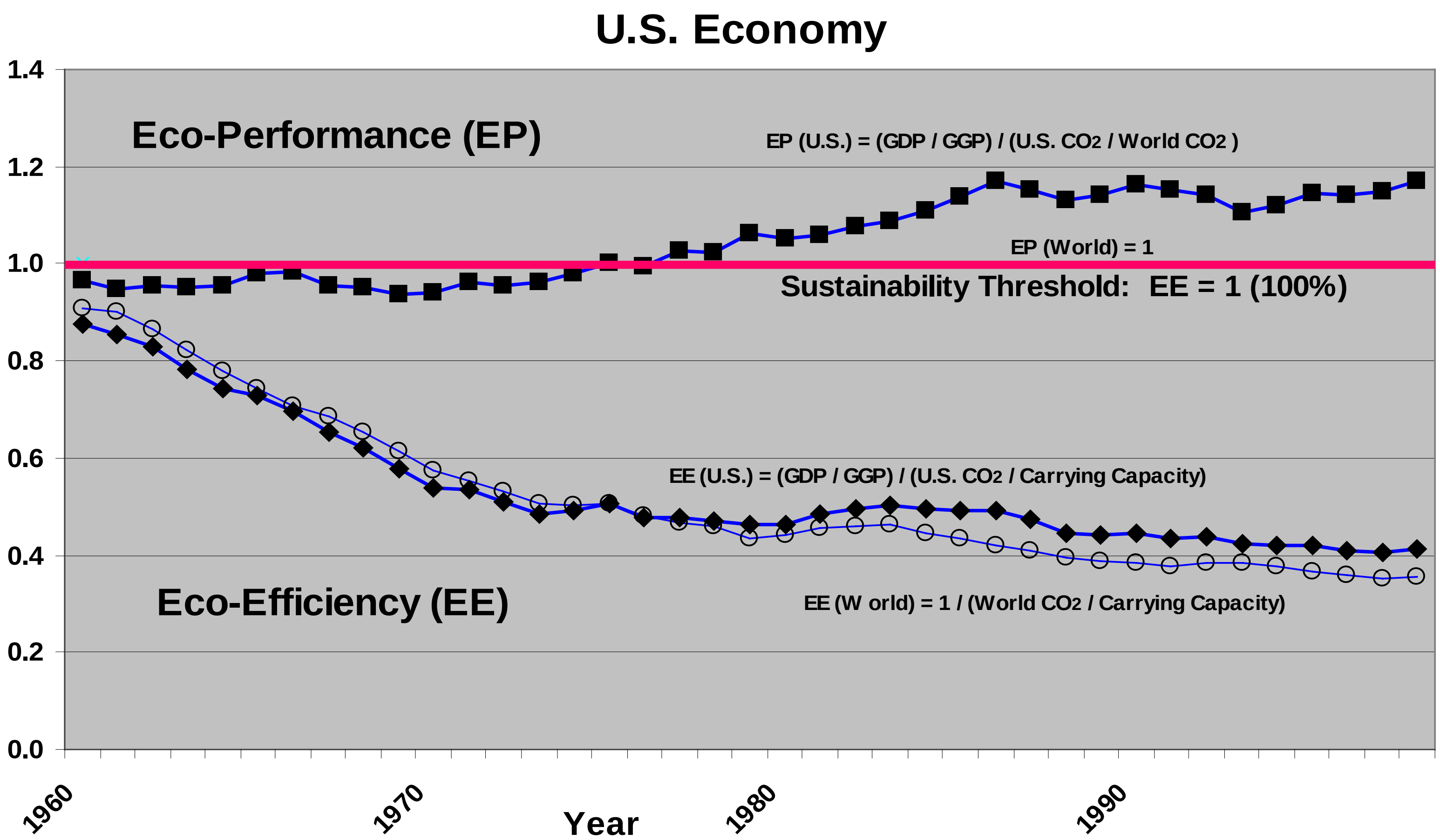
INDUSTRY DATA — STM

L
C
A

ICT	Avg. No. Units Oper. (mid-2006)	Direct CO2 Emissions (% World)	Total CO2 Equivalents (% World)	Revenue / GDP (% World)	EP (%): Eco-Performance * %GDP / %CO_2	EE (%): Eco-Efficiency * %GDP / %ECC
Mobile Telecom	2.4 Bil. Subs.	0.18	0.12	1.6 (.08)	1100	440
Fixed Telecom	1.3 Bil. Fix. Lns. 220 Mil. BB Lns.	0.3	0.2	2.5 (.08)	1000	400
PCs	950 Mil. PCs	0.8	0.5			
Data Networks	31.5 Mil. Serv.	0.6	0.4	3 (0.3)	600	240
TOTAL:	--	1.9	1.2	7 (0.17)	452	181
Entertainment& Media	1.7 Bil. TV, Disc, Portables, etc.	2.7	2	5 (0.4)	213	92
Transport& Travel	Cars, Trucks, Ships, Aircraft	23	15 - 20	11	54	22
Air Travel / Transport	20K+ Civilian Aircraft	2.8	3 - 8	1.3	31	12
Food & Drink	--	15	20 - 30	11	27	11
Buildings	--	~ 50	~ 33	~ 20	48	19

* Preliminary EP and EE for demonstration, assuming Revenue to be the cumulative economic value resulting solely from the CO_2 emissions tabulated by the source company and that valid basic world GDP and emission data were used.

* Carrying Capacity (ECC), based on IPCC analysis, is world CO_2 emission reduced by a factor of about 2.5.


U.S. Economy
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Eco-Performance (EP)
EP (U.S.) = (GDP / GGP) / (U.S. CO2 / World CO2)
EP (World) = 1
Sustainability Threshold: EE = 1 (100%)
EE (U.S.) = (GDP / GGP) / (U.S. CO2 / Carrying Capacity)
Eco-Efficiency (EE)
EE (W orld) = 1 / (World CO2 / Carrying Capacity)
1960
1970
Year
1980
1990

Major Conclusions:

- System-focused integration of Solar Energy research & development processes is a multidisciplinary, collaborative approach requiring:
  - a new understanding, appreciation and management of the infrastructure that leads to product realization and market deployment.
  - that technologies be evaluated in the context of the overall system, taking into account not just local optimization but integration and contribution to overall system performance.
- Better communication of research developments and how they address market needs can lead to positive feedback loops and a more rapid expansion of solar technologies.
- Solar needs more resource investment upstream during the concept and exploration phases to introduce system-level considerations as early as possible. This can reduce the product development interval and facilitate technology transfer.

Alcatel·Lucent

Major Conclusions (continued)

- Solar Industry Drivers should be considered in the context of Systems Thinking.
- SEGIS is an important example of a “System” development program that focuses on the enabling concept of Smart Grids and Distributed Generation.
- DOE’s role is critical in identifying gaps and bottlenecks at the system level and ensuring that they are addressed.


Acciona Nevada Solar One, Boulder City, NV Source: T.M. Peterson

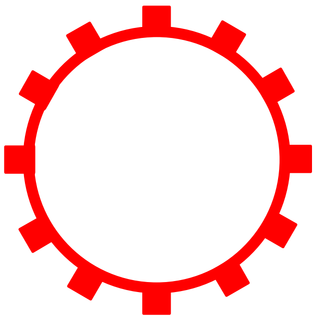
Location:	**Amareleja (Moura, Portugal)**
Power:	45.6 MWp
Trackers:	2,520 (Buskil k18)
Tracker surface area:	141 m2
Total modules:	262,080
Estimated annual output:	93 GWh/year
Equivalent demand (households)	30,000
Avoided emissions:	89.400 tonnes of CO2/year
Surface area:	250 Ha.

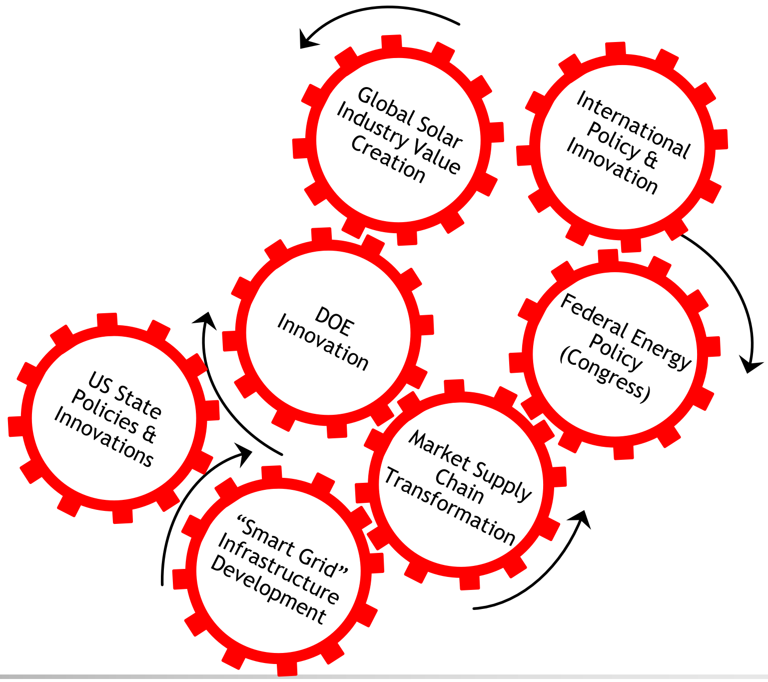
Source: Acciona

African Proverb

If you want to go *fast*, go *alone*…

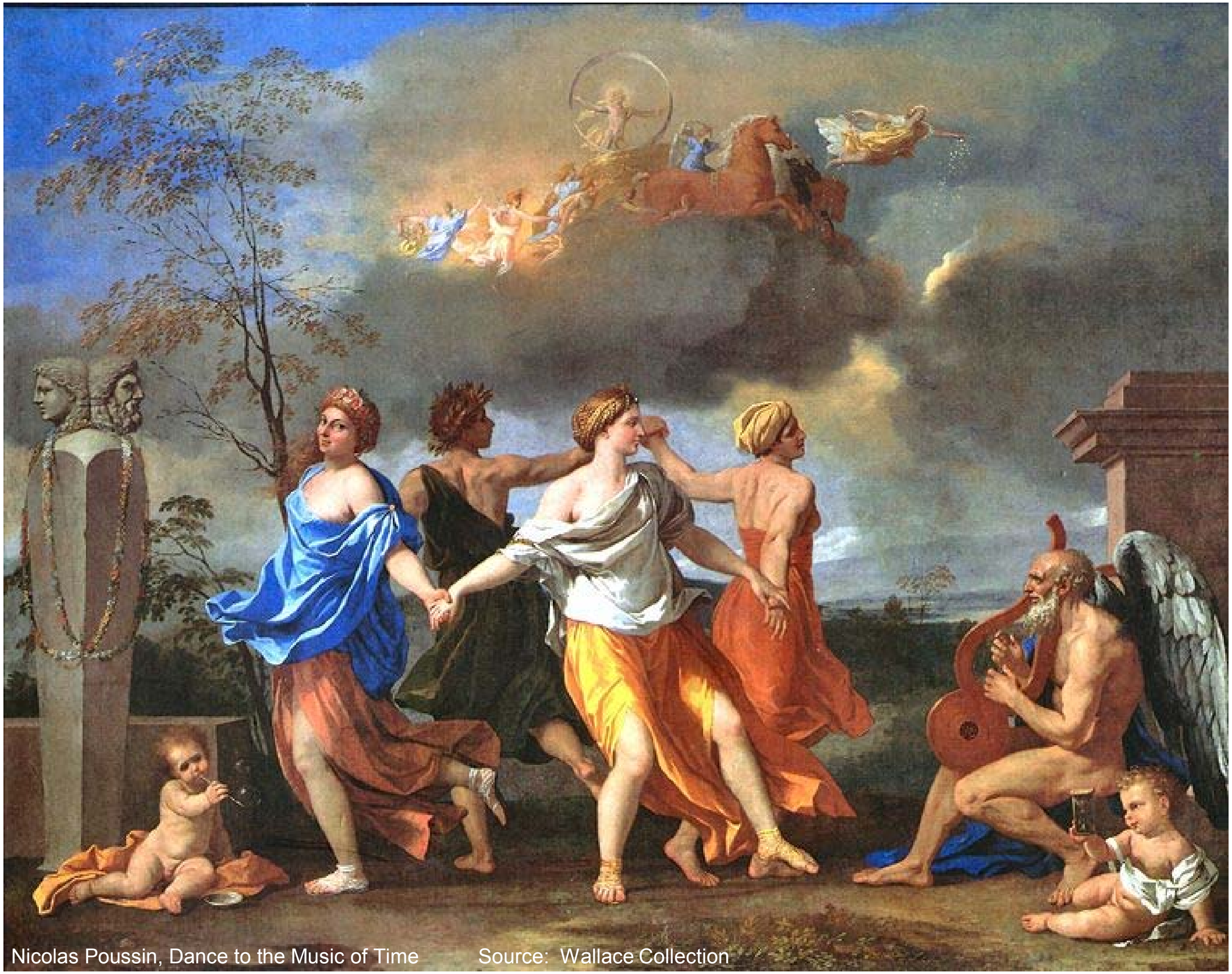
But if you want to go *far*, go *together!*





Alcatel·Lucent

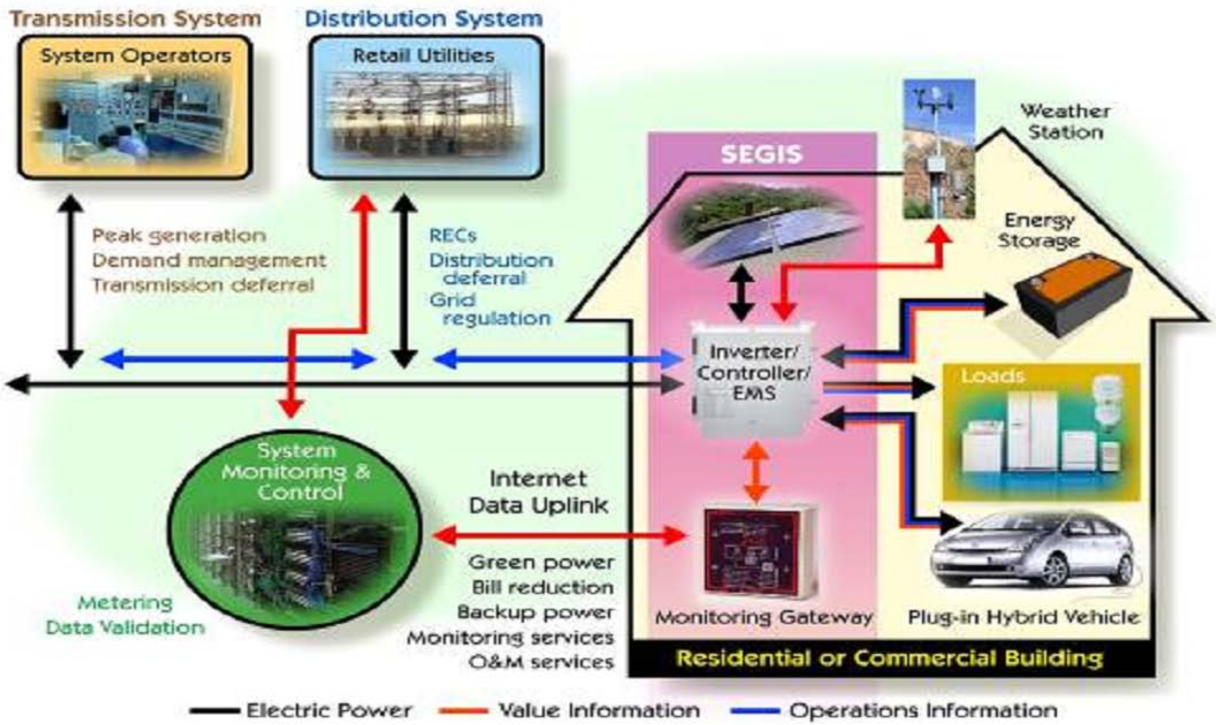
First(?) Senge Diagram



Nicolas Poussin, Dance to the Music of Time Source: Wallace Collection

Current Activities: Distributed PV System Technology Solar Energy Grid Integration Systems (SEGIS)

- SEGIS is a "System" development program focused on new requirements for interconnecting PV to the electrical grid.
- SEGIS is the intelligent hardware that strengthens the ties of Smart Grids, Microgrids, PV, and other Distributed Generation.



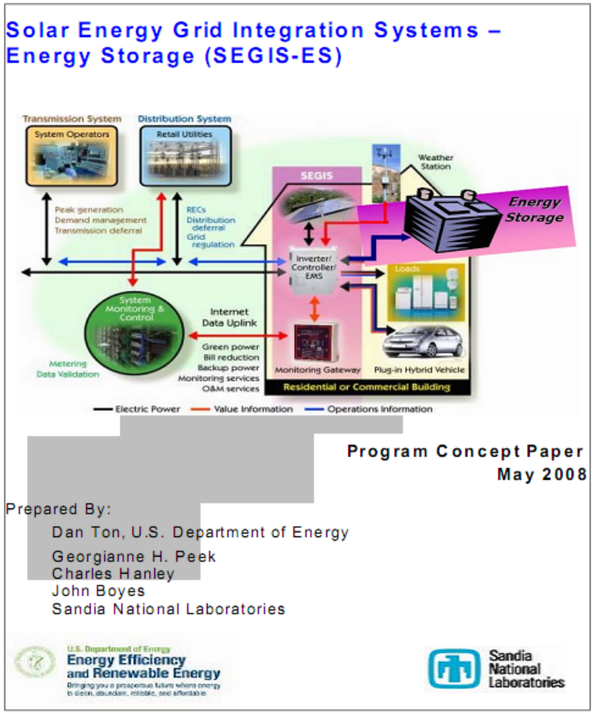
Alcatel·Lucent

Current Activities: SEGIS-Energy Storage

Addressing integration of energy storage with high-penetration PV systems for residential/mall commercial/commercial applications

Program concept paper developed, with key R&D needs identified

- Existing battery systems enhanced for PV integration
- Control electronics
- System-level modeling tools
- Non-battery storage systems


Solar Energy Grid Integration Systems – Energy Storage (SEGIS-ES)

Program Concept Paper
May 2008

Prepared By:
Dan Ton, U.S. Department of Energy
Georgianne H. Peek
Charles Hanley
John Boyes
Sandia National Laboratories

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Sandia National Laboratories

Program concept paper, May 2008

Alcatel·Lucent

NREL and SNL provide a strong base for solar development partnerships with industry

- **Over 200 scientists and engineers with deep understanding of all solar technologies**
- **Areas of expertise**
  - Crystalline silicon and thin-film PV
  - Flat-plate and concentrator PV
  - Process development and engineering
  - System development and testing
  - Measurement and characterization
  - Reliability engineering
  - Next-generation PV technologies
  - CSP components and testing
  - Grid integration and power electronics

Collaboration Types

- Cooperative R&D Agreements (CRADA)
- Work-for-Others
- Technical Service Agreements
- Technology Licensing

Acknowledgements

- John Crowley
- Kevin DeGroat
- John Lushetsky
- Marie Mapes
- Terry Peterson
- Greg Smestad