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Dynamic LCA: concepts and case studies

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Recap InLCA 2008 : Hybrid framework for LCI uncertainty

Uncertainty type	Brief description	LCI method with (generally) higher uncertainty of this type
Data	Data collection errors in input parameters	Process sum
Cut-off	Arises due to processes left out of analysis	Process-sum
Aggregation	Different processes lumped into sectors/super-processes	EIOLCI
Geographical	Inter and intra-national variations in process implementation	EIOLCI
Temporal	**Products and processes evolve over desired time scale**	EIOLCI

Source: Williams, Weber and Hawkins, *in press*, J. Ind. Ecology

The need for dynamic LCA





The need for dynamic LCA

- For retrospective LCA: theoretically, no temporal issue.
- But …LCA intrinsically intends to inform future decisions.
- Not “addition” to conventional LCA, *fundamental* to mission.

Issues and Case studies

Issue	Case study
Process trends	1. Silicon photovoltaics
	2. Iron/steel
Product/process trends	3. Electronics grade chemicals
Changes in user behavior	4. Lifespan of personal computers
Linked process/ product/ usage	5. Semiconductor manufacturing

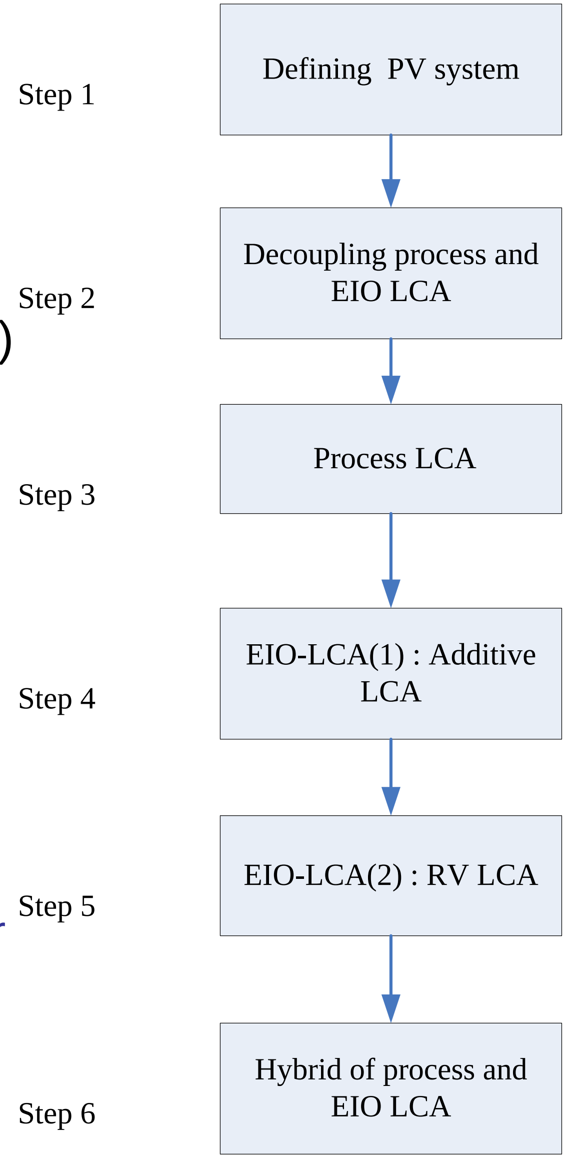
Case study 1: dynamics of PV manufacturing

- Attempt to capture dynamics of supply chain and product
- Goal and scope:
  - **polycrystalline PV modules**
  - Hybrid LCI – collect available process data, correct with EIOLCA model from CMU
  - Energy use and carbon emissions
  - Three years: 1997, 2002, 2007

Source: Zhai and Williams, Env. Sci. & Tech., under review (2009)

Economic balance hybrid LCA methodology

- Hybrid LCA=Process LCA +
  EIO LCA (Additive & Remaining value)
- $E_{Total} = E_P + (E_A + E_{RV})$
- **Process LCA**
  - The results provide detailed energy requirement during the manufacturing processes (Alsema, 1998, 2000, 2005; Stoppato, 2008)
  - The boundary of process LCA is limited
- **EIO LCA**
  - Data--U.S. Benchmark IO table; U. S. Census Bureau. Annual survey of manufacturers, statistics for industry groups and industries
  - Tool– EIOLCA model of Green Design Institute, Carnegie Mellon University

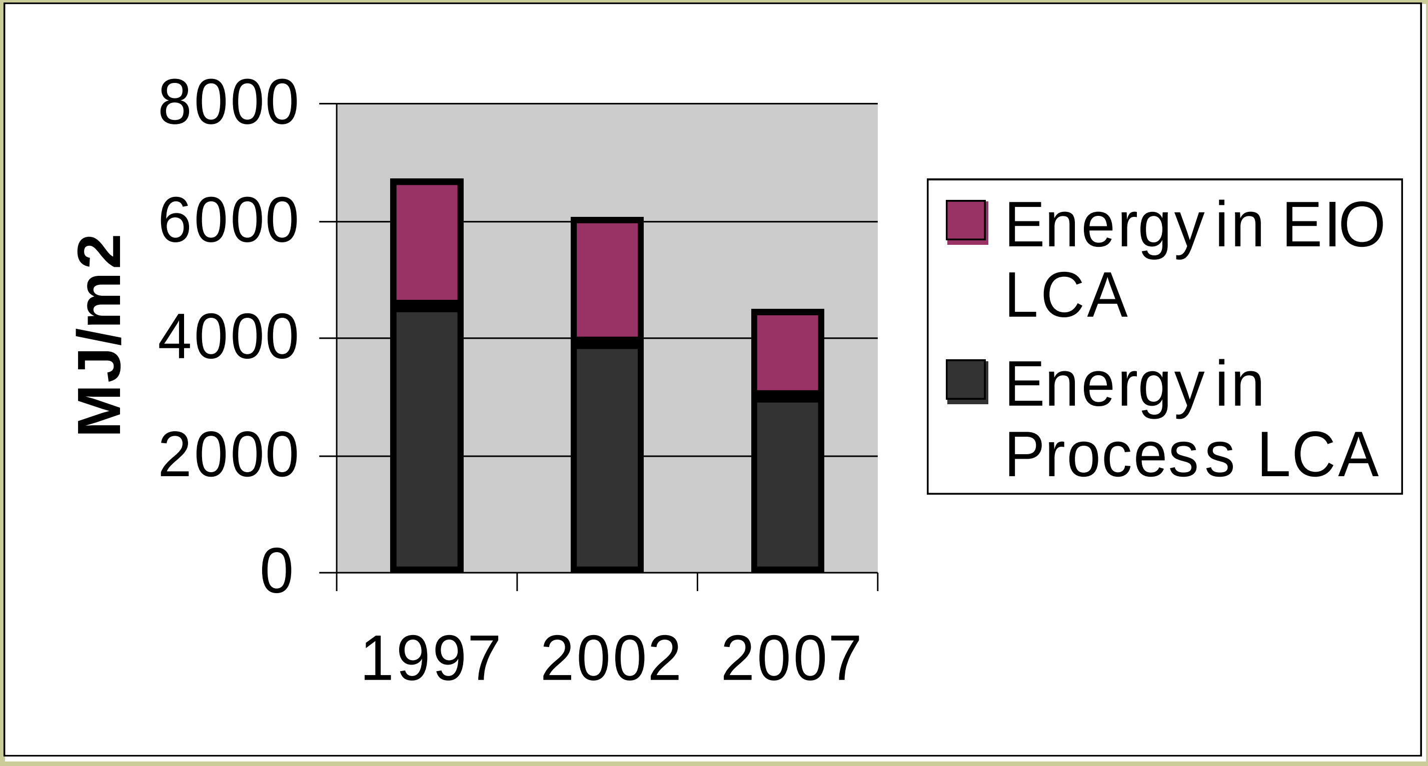


Case study 1: dynamics of PV manufacturing

	Year 1997	2002	2007
Product/process specifications			
Efficiency	13%	13%	13%
Wafer thickness	350 um	285 um	285 um
Silicon purification technology	Siemens	Siemens	80% Siemens +20% Fluidized Bed Reactor
Energy requirements of individual processes (MJ/m2)			
Metallurgical-grade silicon	500	407	407
Polysilicon purification	1785	1453	1226
Casting	750	610	611
Wafering	250	204	204
Cell processing	600	600	600
Module assembly	350	350	350
Frame	300	300	300
Module Total	4535	3925	3698

Source: Zhai and Williams, Env. Sci. & Tech., under review (2009)

Summary of Process and EIO LCA results of 10 years



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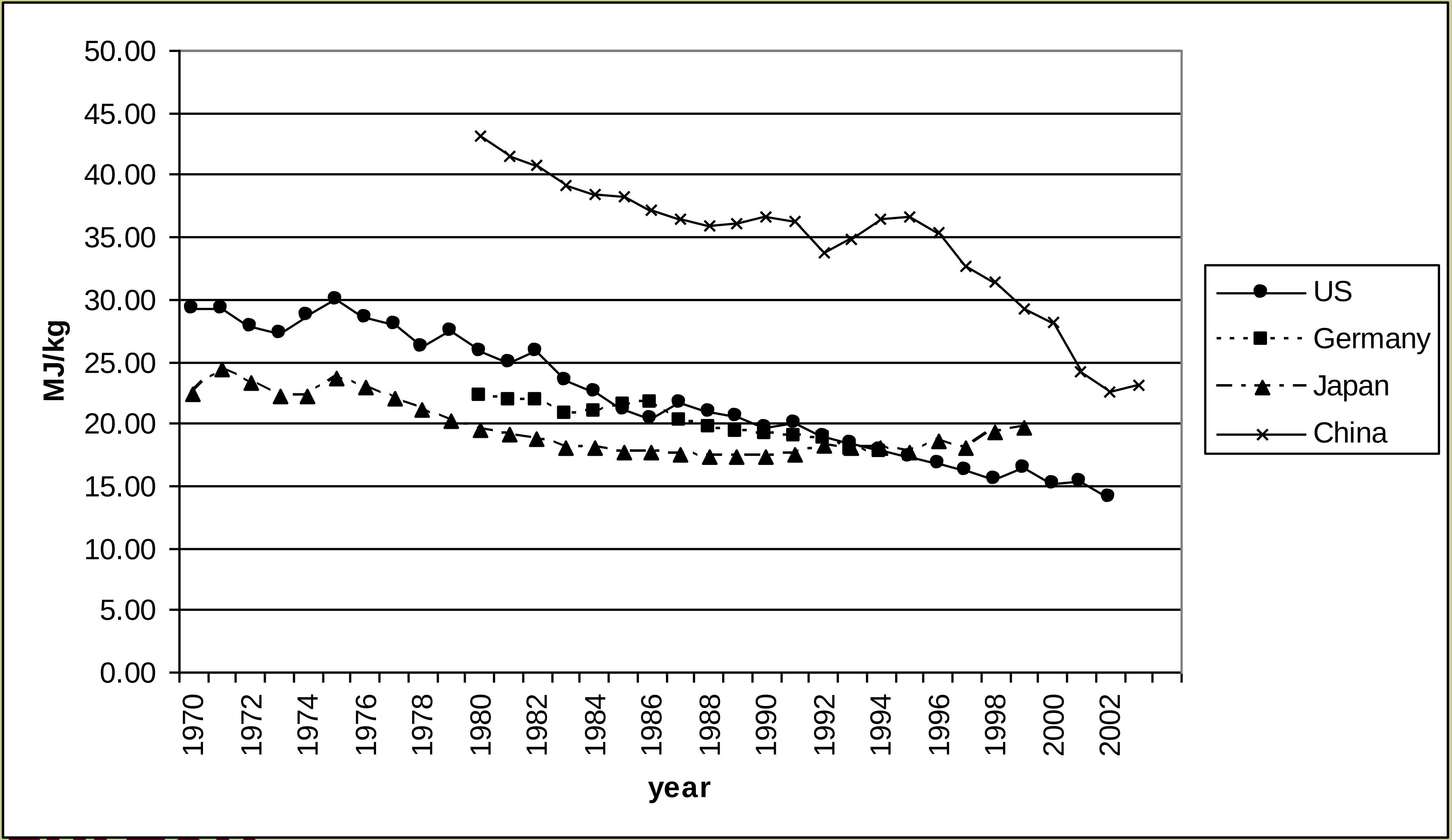
Source: Zhai and Williams, Env. Sci. & Tech., under review (2009)

Case study 2: forecasting trends

- What is time scale of future validity of LCA result?
- One approach: extrapolation of trends
- Method:
  - Set desired future validity of study (e.g. 5 years)
  - Track retrospective trends (e.g. 5 years previous to present)
  - Error bar

Source: Williams, Weber and Hawkins, *in press*, J. Ind. Ecology

Case study 2: iron/steel energy use



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Source: Williams, Weber and Hawkins, *in press*, J. Ind. Ecology

Defining temporal validity: 5 years out

Country	2005 baseline value (MJ/kg)	2010 expected value (MJ/kg)
US	13	10
Japan	19	19
China	25	20
Average weighted according to production share	21.8	18.1

Source: Williams, Weber and Hawkins, *in press*, J. Ind. Ecology

Case study 3: Energy needs to purify water for semiconductor manufacture

- In previous cases, products (PV and steel) relatively unchanging
- Consider example of rapid product change: chemicals for semiconductor manufacturing
- Case study: estimate energy use as a function of water purity.

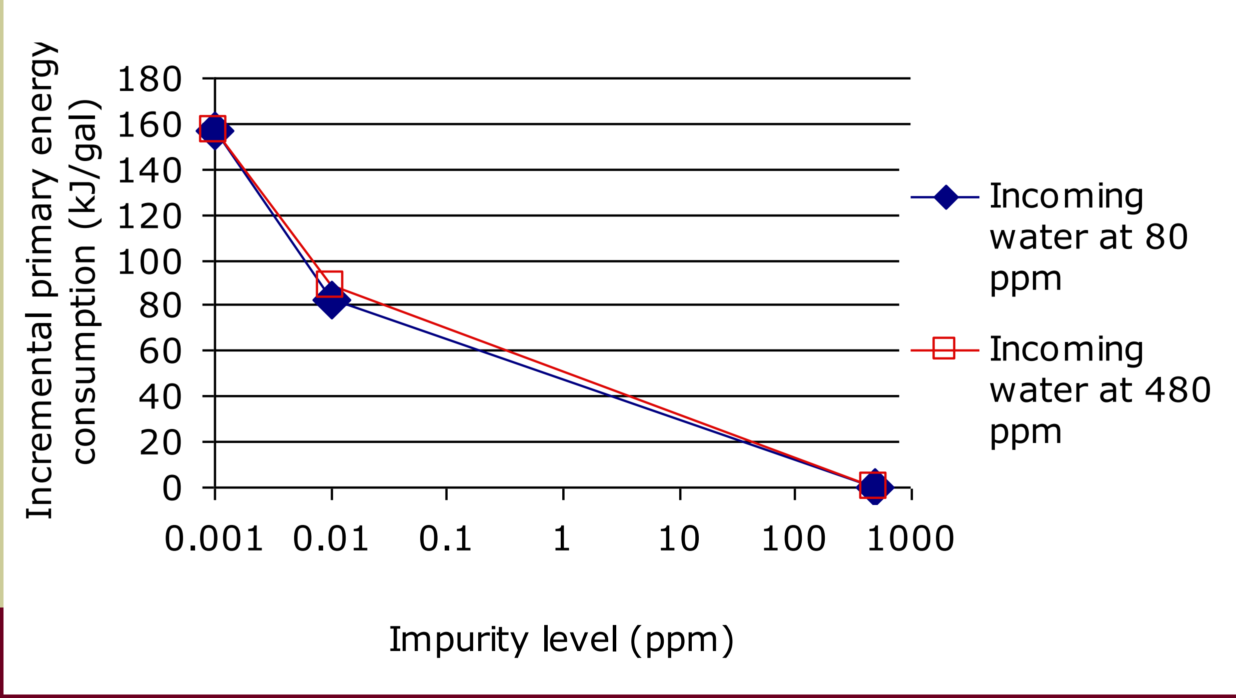
Source: Deng and Williams, Proceedings of IEEE ISEE (2008)

Case study 3: Energy needs to purify water for semiconductor manufacture

Technology node	250 nm	180 nm	130 nm	90 nm	65 nm
Particles (cts/l) 0.1-0.2 µm	350	250	100	100	100
Total silica (ppb)	3	2	1	0.5	0.5
Aluminum (ppt)	10	5	3	3	1

Excerpt from water specifications for the semiconductor industry

Source: Krishnan, Williams,
and Boyd, IEEE Int. Symposium on Electronics and the Environment (2008)



Case study 4: lifespan of personal computers

- Usage patterns of products can *evolve*, affects LCA
- Lifespan drives scale of manufacturing phase impacts
- Explore studying lifespan trends in personal computers in university
- lifespan = disposal year – purchase year

(i.e. Organizational lifespan)

Source: Babbitt, Kahhat, Williams and Babbitt, *Env. Sci &Tech.* (2009)

Case study 4: lifespan of personal computers

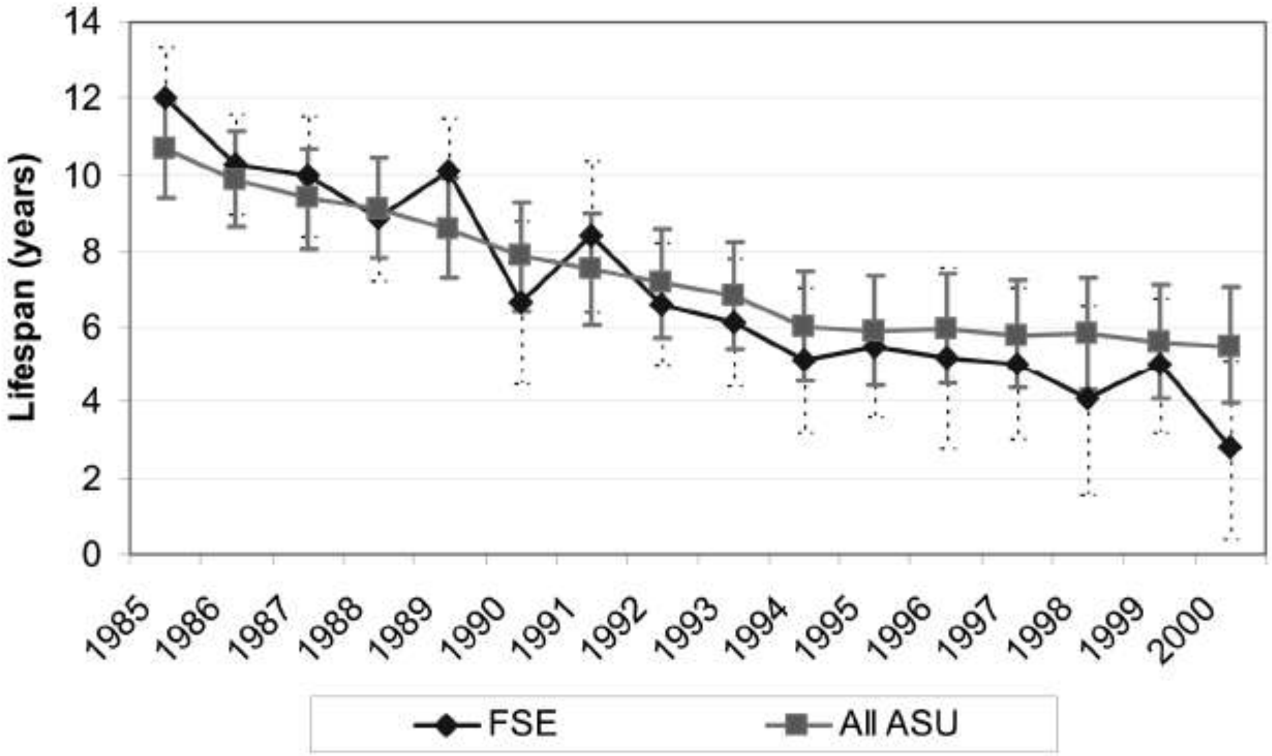


FIGURE 2. Mean lifespan of PCs at ASU and subsampled in the Fulton School of Engineering (FSE). Error bars are standard deviation among all computers in each sampling group.

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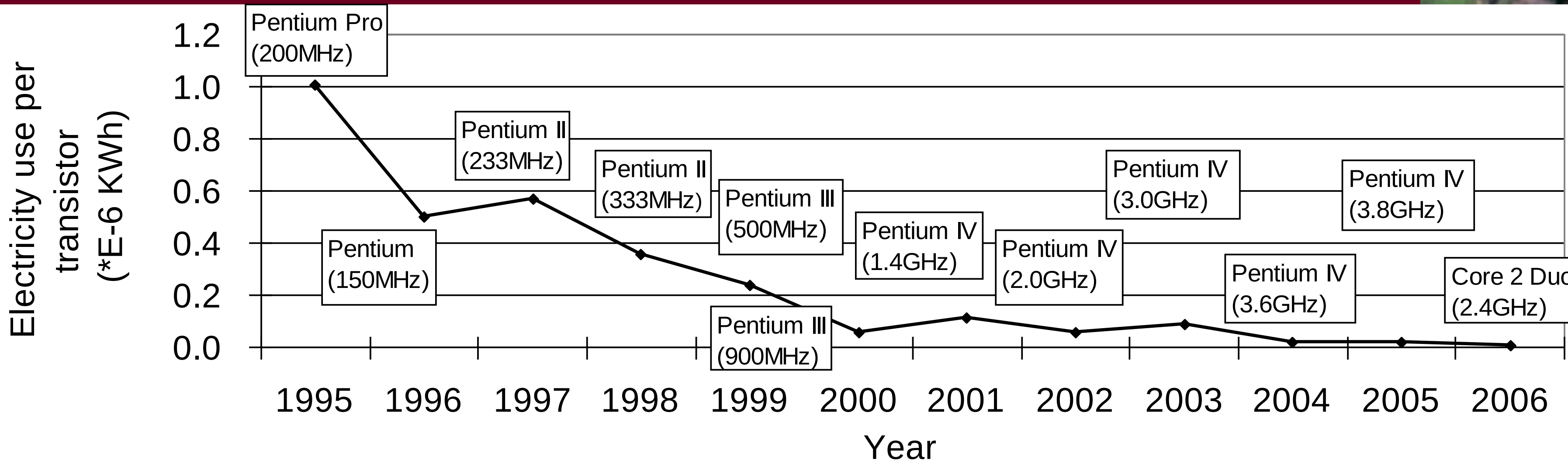
Source: Babbitt, Kahhat, Williams and Babbitt, Env. Sci. &Tech. (2009)

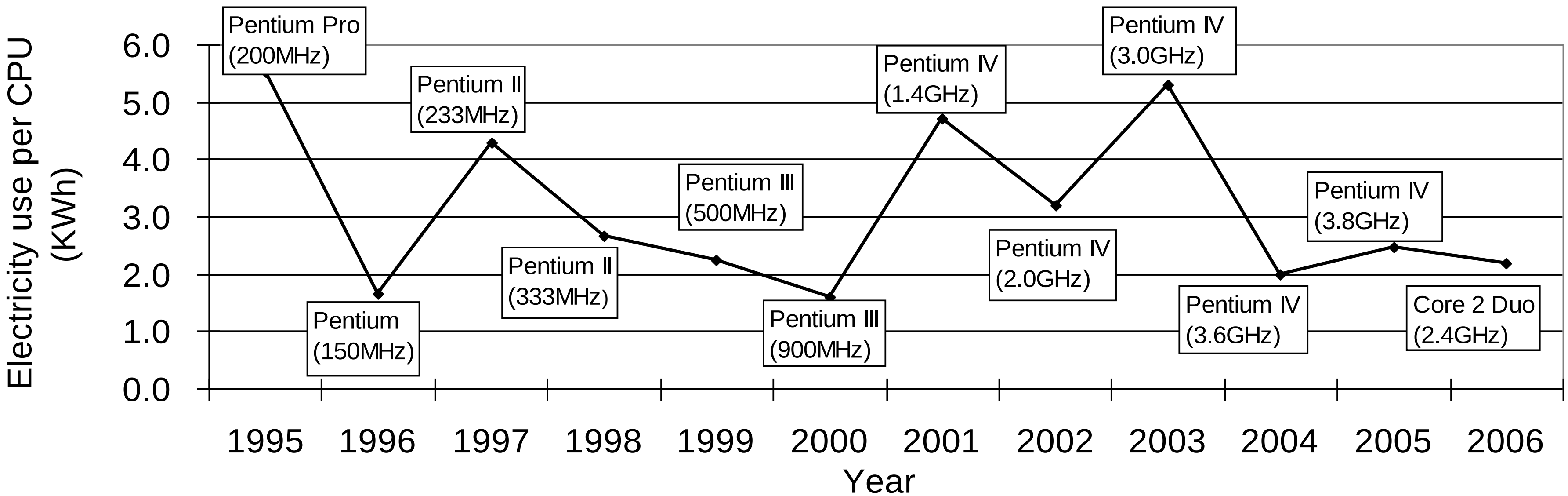
Case study 5: semiconductor manufacture

- The *functionality* of products also evolves
- Case study: track energy use trends in computer microprocessor manufacturing with two normalizations:
  - Functionality: energy use per transistor/flops/speed of processor
  - "typical product": energy use per common processor for a given year

Source: Deng and Williams, in review, J. Industrial Ecology (2009)

Manufacturing energy use per transistors versus per typical CPU





Source: Deng and Williams, in review, J. Industrial Ecology (2009)

Case study 5: semiconductor manufacture

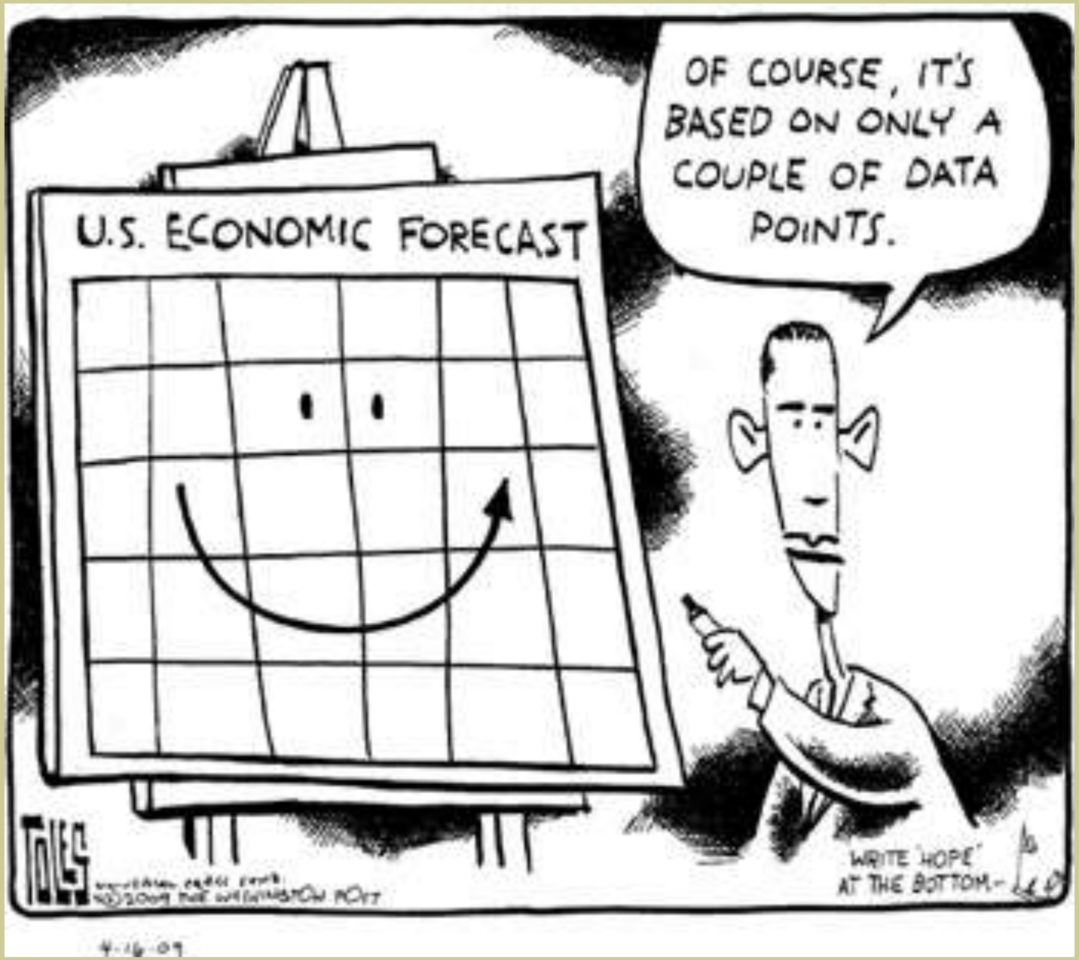
- Energy per typical CPU almost static, Energy per functionality evolves rapidly
- Idea: can a different *conceptualization* of functional unit be more temporally robust?
- i.e. replace

LCI of a computer with specs X in year Y

With

LCI of a “typical” computer in year Y

Source: Deng and Williams, in review, J. Industrial Ecology (2009)


U.S. ECONOMIC FORECAST
OF COURSE, IT'S BASED ON ONLY A COUPLE OF DATA POINTS.
TOLES
WRITE 'HOPE' AT THE BOTTOM.-
4-16-09

Discussion

- Changes in processes, products, usage patterns can *all* affect LCA
- Expanded modeling framework beyond usual LCA including:
  - Technological forecasting
  - Understanding trends in functionality and consumer demand
- Future work: lots…

Thank you for
your attention.

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