Targeting for Life-Cycle Control of Greenhouse Gas Emissions

Toshko Zhelev

Department of Chemical & Environmental Sciences
Charles Parsons Initiative – Energy and Sustainable Environment
University of Limerick, Ireland

Outline

- Background
- Objectives
- Methodology
- Emission targeting
- Not just “fuel mix”
- Considering dynamics
- Life cycle concept
- Conclusion/future plans

Background

- GHG & Kyoto
  - Past = statistic
  - Present = measurement
  - Future = forecasting
- Is this all?
  - Active approach "To Do" against
  - Passive approach
- Goals:
  - Targeting
  - Analysis
  - Guidelines
  - Decision making
  - Design/redesign

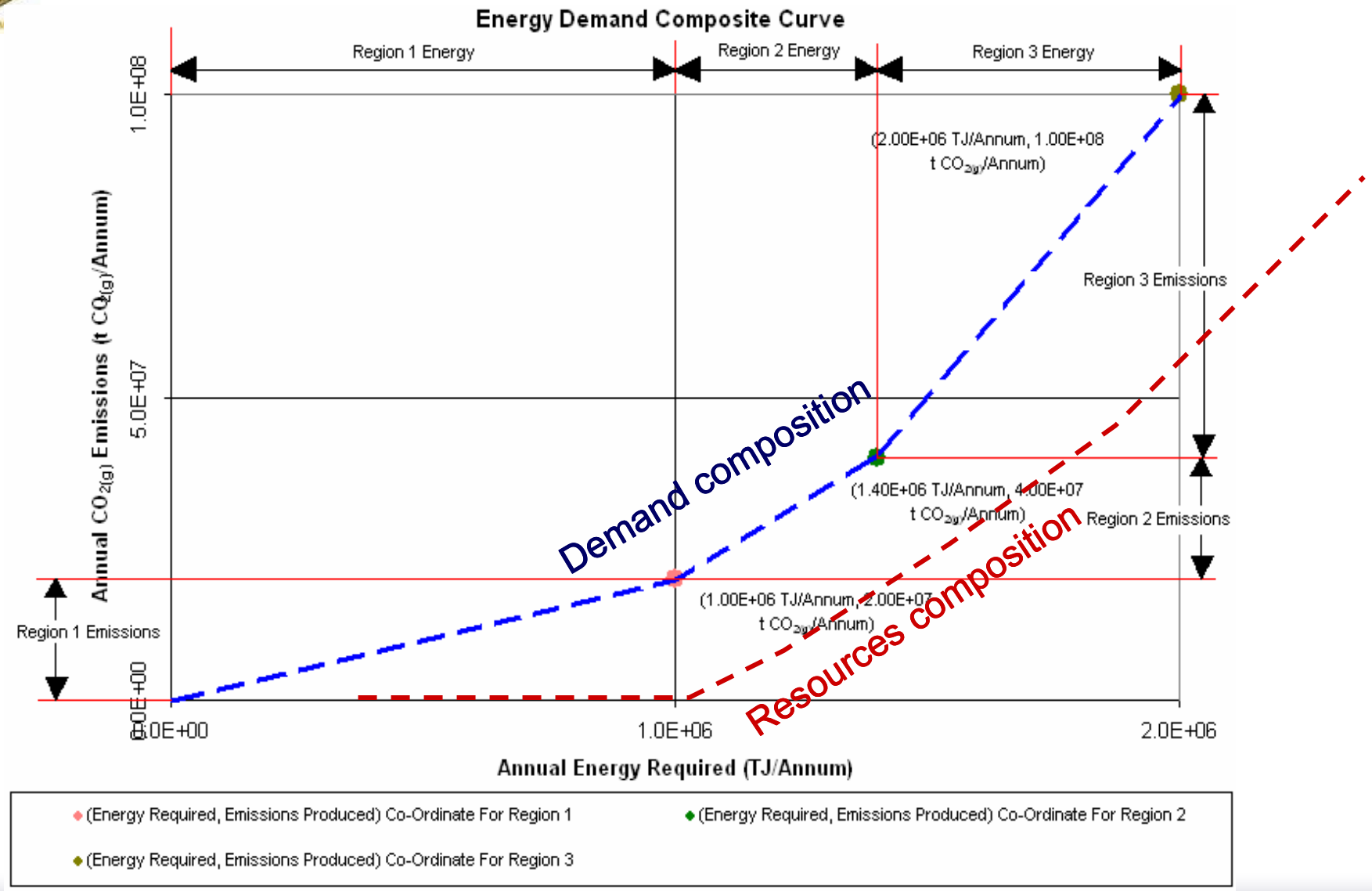
Objectives

- More comprehensive analysis (Life-cycle approach to CO_2 management)
  - From the past, though today, towards the future
- System + Life cycle approach
  - Not only analysis (numbers), but identification of causes, bottlenecks & actions
- Guided management
  - Reaching beyond evaluation of alternatives
  - Design changes and *CO_2 generation Planning*

Methodology

- Conceptual approach
- CO_2 targeting (Tan & Foo,…)
- Extended targeting & planning (Crilly et al)
- eMergy analysis (common denominator)
- Considering dynamics of generation
- *"End-of Pipe"* (Post-generation) treatment
- Using early stage energy efficient technologies (such as EMINENT)

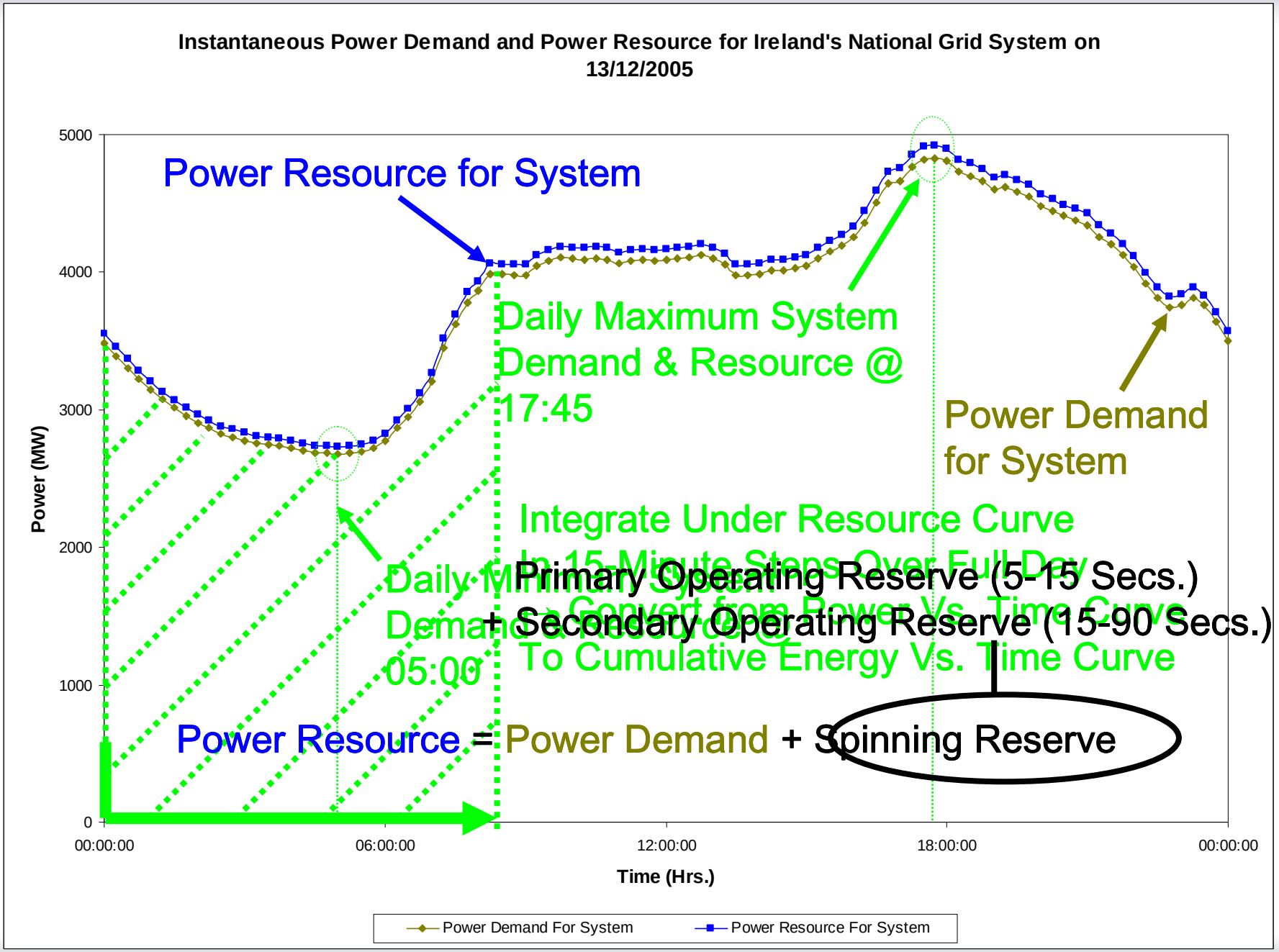
Carbon Emission Targeting & Planning

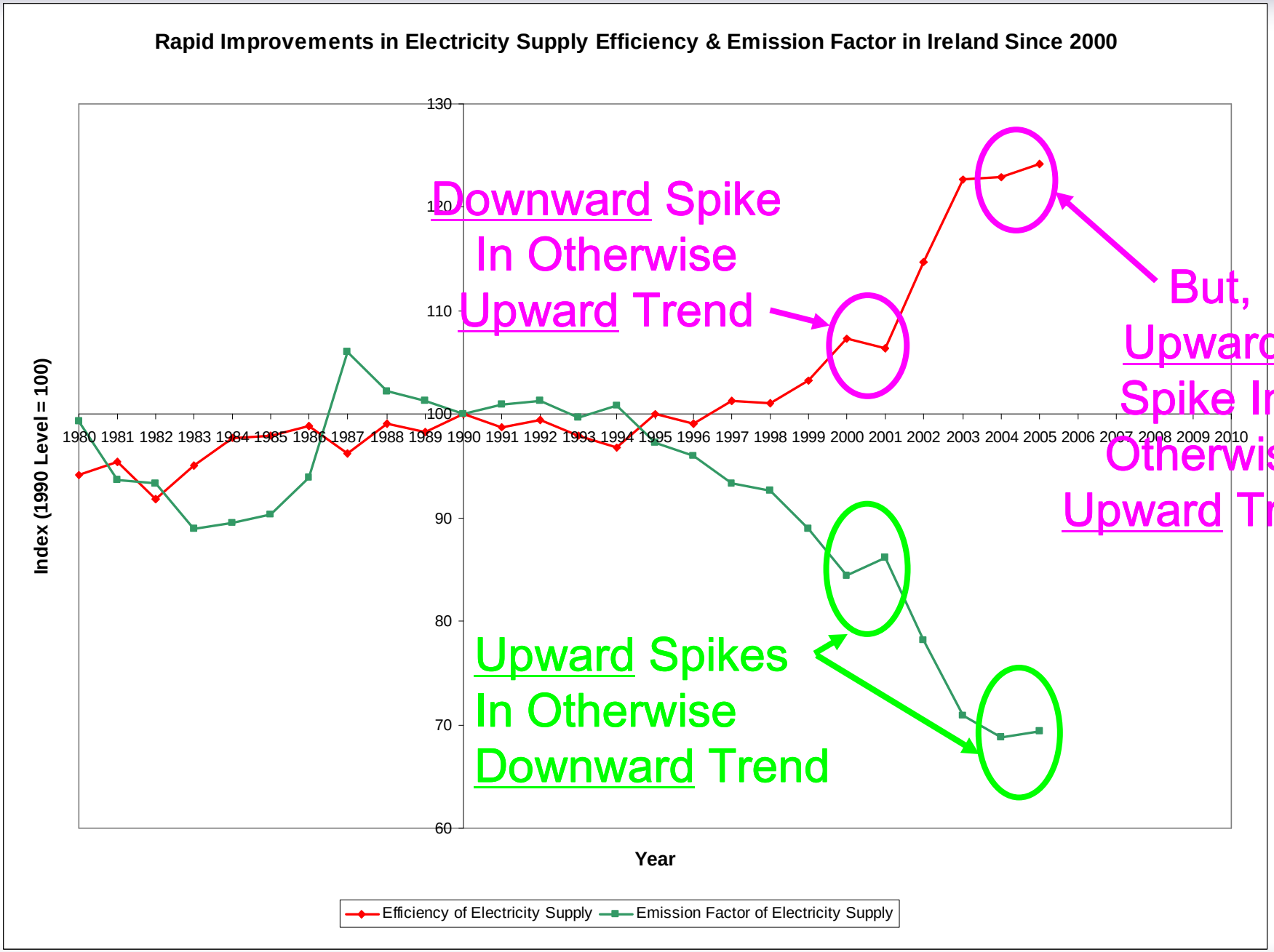


Not Just “Fuel Mix”

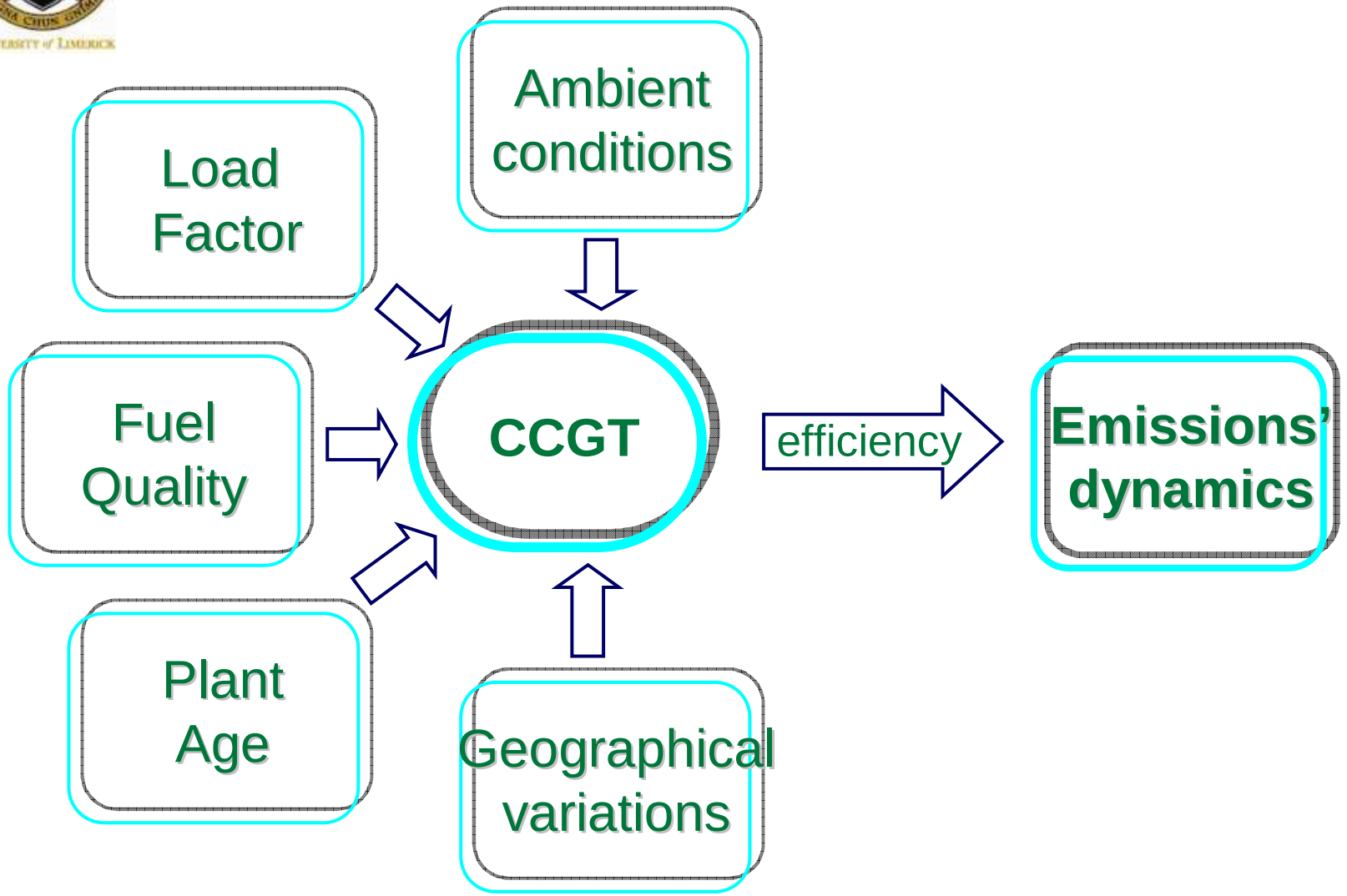
Considering Dynamics

- Example: case study of Crilly & Zhelev (2008) – Irish electricity sector
- Variation of electricity demand over course of a day:
  - Tuesday 13th Dec. 2005





Example CCGT



CO_2 DYNAMICS

- Fluctuation of prices over time (forces changes of the fuel mix not only emissions)
- Amortisation (aging) of equipment with time – leads to lower efficiency and higher emission level
- Operation dependent emission level (load & time) (thermal efficiency = emission difference)
- Weather dependent emission level (time)
- Analysis considering “Pinch jumps”

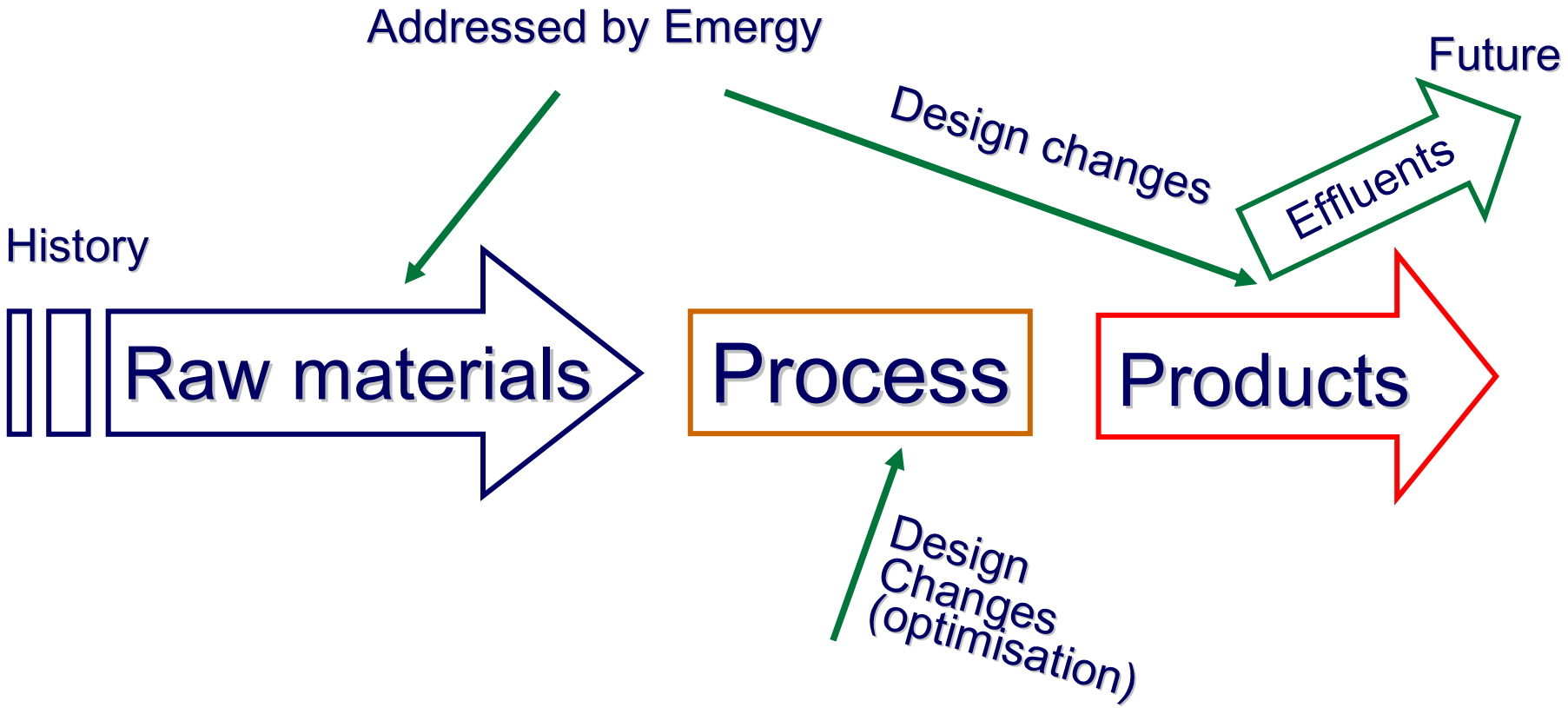
eMergy – appraisal of sustainability

- **Appraisal of the *actual environmental cost*.**
- **Evaluate the main *flows of energy and materials including human systems***
- **Index of *environmental performance* based on emergy**
- **Based on thermodynamics - *enables integration of economic and ecological aspects***

EMERGY SYNTHESIS

- The emergy evaluation procedure is called “Synthesis” instead of “Analysis”
- Emergy synthesis = decisions on environmental and economic alternatives
- It is hoped that Emergy Evaluation can help *form a quantitative basis for sustainable decision making*.

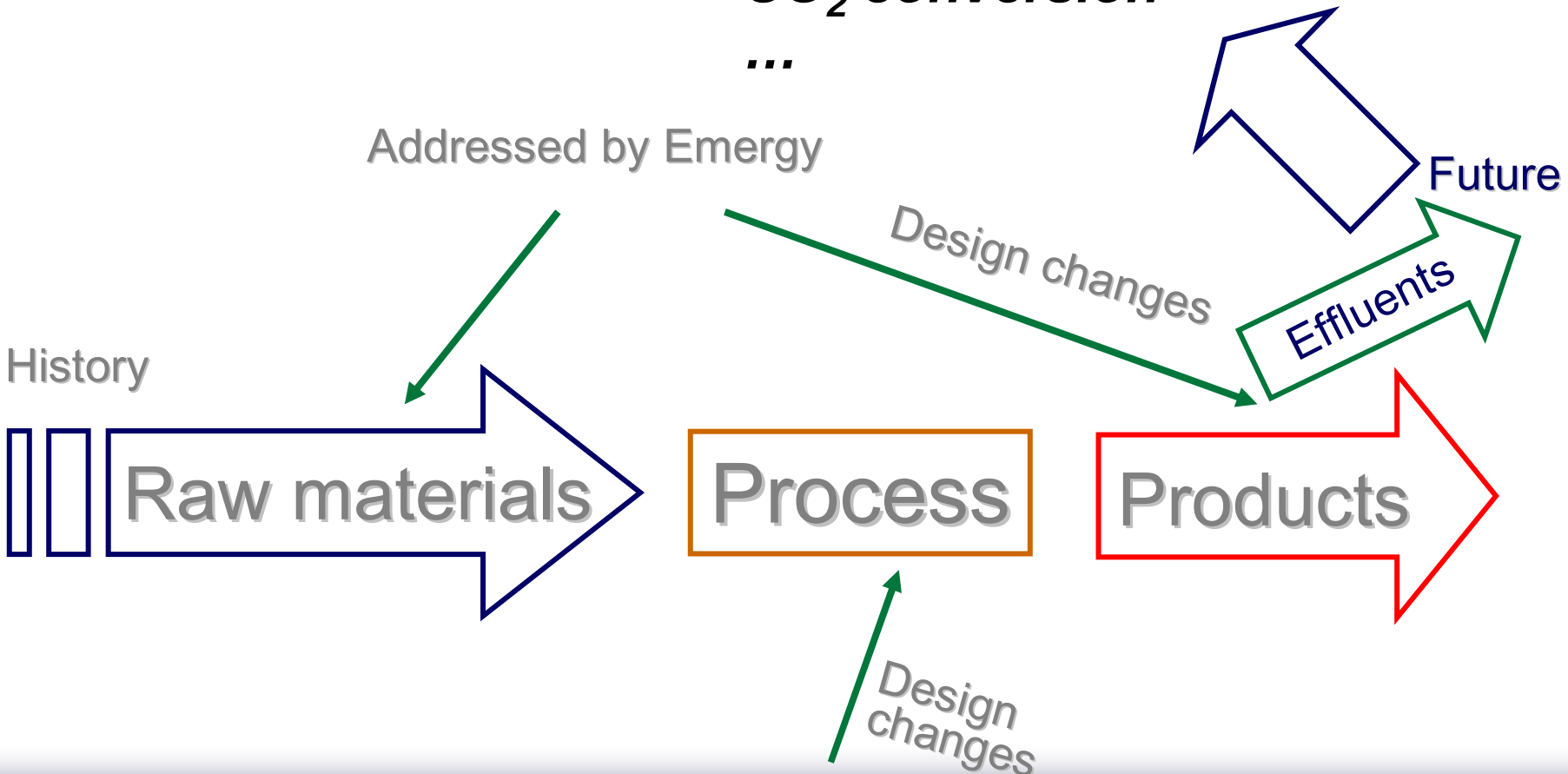
Multiple Resources Management
Combined eMergy – Pinch Analysis



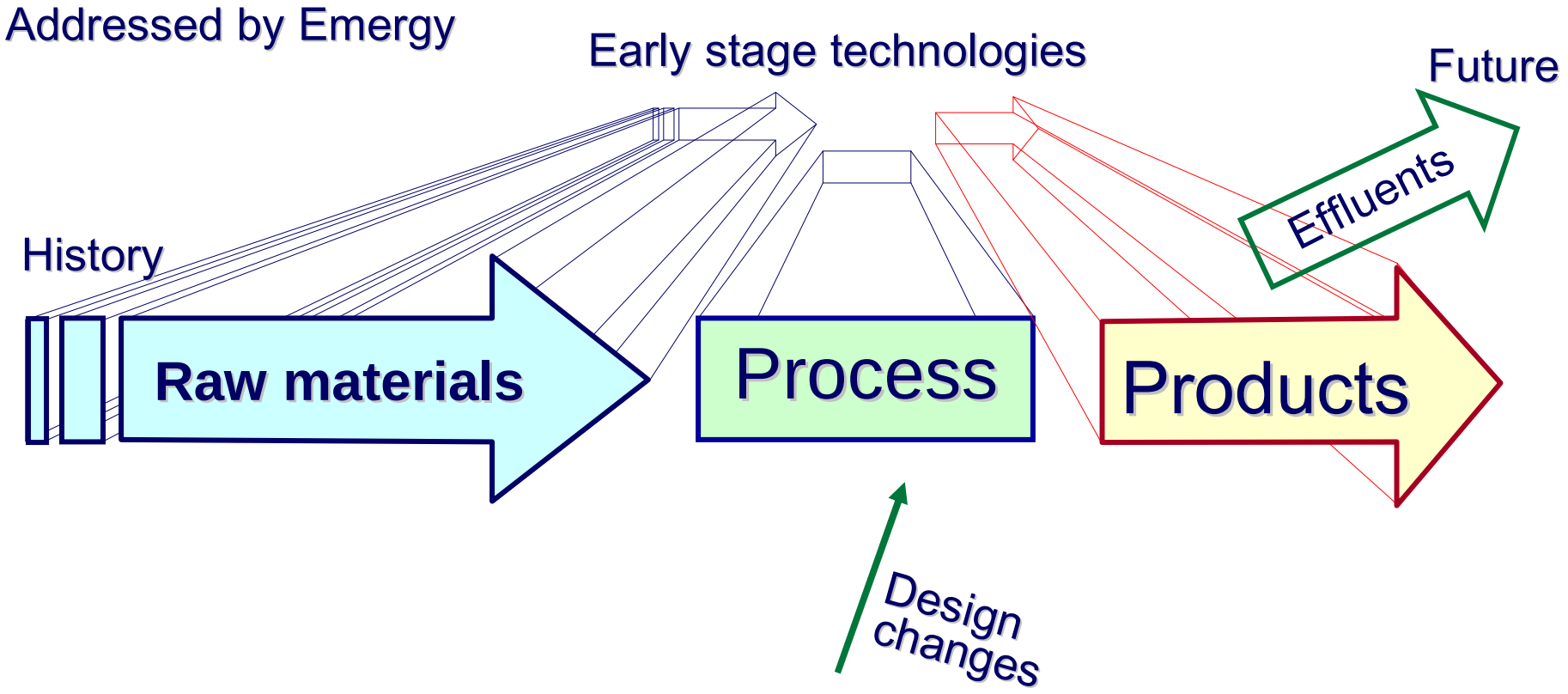
Point 1 – waste + energy recovery
Point 2 – going beyond evaluation of alternatives?

Post-generation Treatment

CO_2 capturing
CO_2 storage
CO_2 conversion
...



Sustainable energy generation – The 3rd Dimension



Point 1 – waste + energy recovery
Point 2 – going beyond evaluation of alternatives?

Forecasting the fuel map

- Forecasting *emission mix* (not fuel mix) and what forces emission changes
- Forecasting the *fuel map*:
  - fading pit resources
  - Increased gas prospective
- Forecasting the *prospective energy efficiency technologies*
  - CHP
  - Gasification
  - Fluidised bed
  - Pinch

Fuels + technologies

- Combination of fuels and fuel efficient technologies (example: converting from fuel oil to gas; converting from coal to powderised coal or slurry)
- EMINENT – early stage promising technologies
- Energy efficiency/conservation projects

I hate indicators

Energy efficiency indicator by type of fuel

$$\mathrm{EEI}_{j,k} \cong \frac{E_{j,k}}{\sum m_{i,k}\mathrm{SEC}_{i,j,0}}.$$

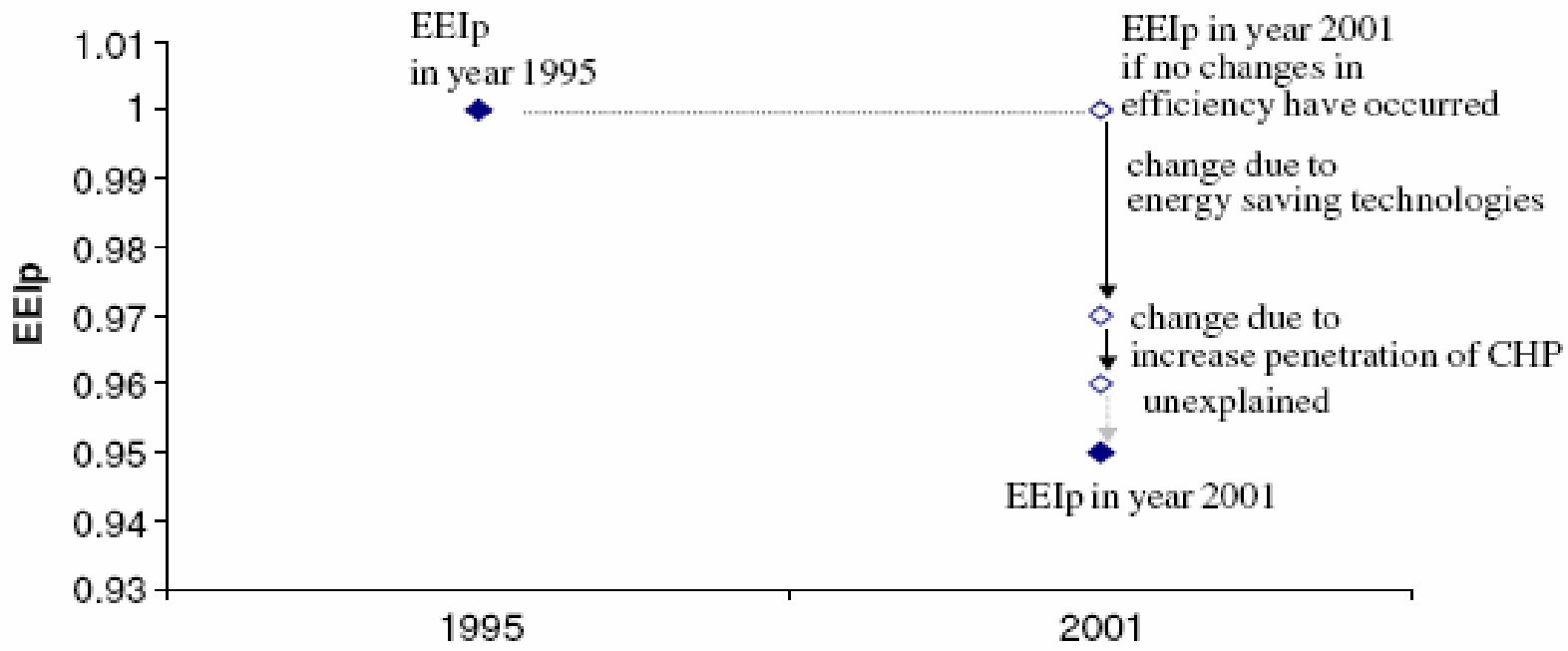
Energy efficiency indicator in primary energy

$$\mathrm{EEI}_{p,k} = \frac{E_{p,k}}{\sum m_{i,k} \cdot (SEC_{\mathrm{ref}\ i,j,0} \cdot f_j)} = \frac{\sum E_{k,j} \cdot f_j}{\sum m_{i,k} \cdot (SEC_{\mathrm{ref}\ i,j,0} \cdot f_j)}$$

k	- is the year of the analysis
0	- denotes the base year,
j	- type of fuel (electricity, fossil, fuels/heat),
$\mathbf{EEI}_{k,j}$	- energy efficiency indicator in year k for fuel j,
$\mathbf{EEI}_{p,k}$	- primary energy efficiency indicator in year k,
$E_{j,k}$	- energy demand for fuel j; in year k;
$\mathbf{E}_{p,k}$	- primary energy demand in year k,
$m_{i,k}$	- physical production of product i in year k,
$\mathbf{SEC}_{i,j,0}$	- energy use to produce product i, for fuel j
f_j	- conversion factor from fuel j for final use to primary

Ramı´rez, C.A. et al, Energy policy, 34, 2006, 1720.

Technology penetration



Causes of changes in the EEI*p* for the period 1995–2001.

Ramı´rez, C.A. et al, Energy policy, 34, 2006, 1720.

Conservation projects alone - saved in Holland 3780 TJ of primary energy in 2001. These savings + increased CHP penetration led to 80% of the change in the EEIp between 1999 and 2001.

It was found that savings on electricity have not been very important.

Conclusion

- From a *Steady state* to *Dynamic* GHG emission targeting and forecasting
- Life-cycle approach [History *(statistic)* – Processes *(targets)* – Future *(forecasting)*]
- Advanced *post-generation* treatment
- Introducing the 3rd dimension – promising technologies (pebble bed, CO_2 conversion, Clean coal…)
- From *Google Erath* to *Fuel Earth*