Internalising externalities in MARKAL–TIMES models,

a contribution of different approaches

GianCarlo Tosato and Denise Van Regemorter

International Energy Workshop, 24-26 June 2003, IASA

General Question Addressed

Is it possible to evaluate full costs and benefits - i.e. direct and external - of energy policies and of future energy systems, by balancing the trade-offs among “cradle to grave” energy security, global and local environment protection, full economic costs?

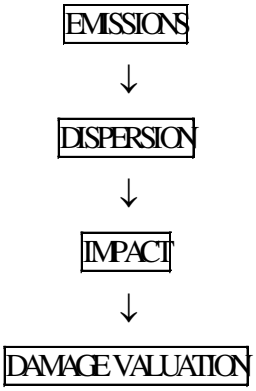
Integration of three approaches

- Life Cycle Inventory and Assessment of energy technologies: **LCA**
- Monetary valuation of externalities associated with energy production, transport, conversion and use: **ExternE**
- Energy and environment scenarios building via technology rich mathematical programming partial equilibrium models: **the Integrated MARKAL-EFOM System (TIMES)**

Life Cycle Assessment

- Evaluation of the 'cradle to grave' impact of a commodity in terms of scarce resources (energy/environment)
- Based on Life cycle inventories of all commodities and processes entering in the production, use and final disposal of the commodity
- Comparison with weighing of the different impacts of similar products/processes

ExternE, the impact pathway methodology



Energy models generated with MARKAL–TIMES

- Energy/environment decision making processes within a partial equilibrium framework
- Represented as a maximization of the consumers and producers surplus, taking into account the production possibilities and any environmental/energy security or other target constraints

Main Differences between the approaches

- System scope
  - LCA and ExternE linked to the process analysed but covering the whole system linked to that process
  - TIMES covers mostly the whole energy system but with loose links outside the energy system
- Economic rationale
  - LCA and ExternE use a simulation approach for comparison between options
  - TIMES analyses the trade-off within the energy system with an optimisation framework

Main Differences between the approaches

- Time horizon and dynamics
  - The three methodologies have a life cycle approach with a time horizon going beyond the time horizon of a single process
- Units/Numeraire
  - The common unit for the evaluation of different options is the economic value in ExternE and TIMES; in LCA other criteria for the aggregation are also used

Main Differences between the approaches

- Geographical definition
  - ExternE and LCA, mostly location specific but with transboundary aspect
  - TIMES, local, national, regional or global but mostly national
- Level of detail
  - LCA and ExternE (though a bit less) very detailed analysis
  - TIMES no specific limit but the capacity to digest the equilibrium solution

A first Integration of MARKAL and ExternE for Belgium

- Problem addressed
  - Global Warming through GHG emissions linked to energy
  - Local Pollution through SO2, NOx, VOC, PM emissions linked to energy and Ozone
- MARKAL Adaptation
  - Damage function added to objective function for the different pollutant, based on ExternE computation
  - Damage categories: public health and territorial ecosystems and materials

Evaluation of the integration with Policy Scenarios

- Scenario 1 : local air pollution
  tax on SO2,NOx,VOC and PM emissions equal to the total damage (in Belgium and abroad)
- Scenario 2 : global warming
  the Belgian Kyoto target for GHG emissions:
  -7.5% in 2010 compared to 1990, same rate for 2010-2030
- Scenario 3 : global warming and local air pollution

Welfare and Damages over the entire horizon

(*10^6ECU90)* (differences with reference scenario)
(1990-2030)

	LAP	GHG	LAP-GHG
Discounted welfare, excluding environmental benefit	-987.5	-4336.3	-4802.4
Discounted local environmental benefits	2145.7	1429.2	2805.7
Net welfare effect	1158.2	-2907.1	-1996.7

Welfare and Damages per period

(undiscounted, differences with reference scenario)

	2010	2020	2030
Welfare, excluding environmental benefit(10^6ECU90)			
LAP	-257.6	-396.9	-356.6
GHG	-713.7	-2652.6	-7707.4
LAP-GHG	-843.9	-2733.6	-7765.0
Local environmental benefit (10^6ECU90)			
LAP	+580.0	+711.7	+619.4
GHG	+300.8	+772.7	+1289.6
LAP-GHG	+754.2	+1101.5	+1298.6
Net welfare benefit (10^6ECU90)			
LAP	+322.4	+314.8	+262.8
GHG	-412.9	-1879.8	-6417.9
LAP-GHG	-89.6	-1632.1	-6466.4

Towards an integrated tool - 1: from LCI/A to TIMES-ExternE, now

Around 80% of Climate Change damages originate from the energy demand and supply system. A similar weight applies to local / regional pollution.

How many and what products account for a similar amount of damages when “cradle to grave” resource “costs” are accounted for?

Process oriented Life Cycle Inventories (P-LCI) based upon present day technologies identify the minimum set of products and processes to be included in the flexible structure of the combined TIMES-ExternE model.

Towards an integrated tool - 2: from TIMES-ExternE to LCI/A, dynamic

Scenarios resulting from the regional models built with the combined TIMES-ExternE generator are used to update in different future years the set of processes and products accounting for the highest damages in different time horizons.

With these elements, the micro comparison of different products / processes becomes dynamic and scenario / policy dependent.

Towards a fully integrated tool

- ExternE provides LCA and TIMES with the economic evaluation of damages related to energy supply and use options
- LCA adds to the ExternE procedure and to TIMES a “cradle to grave” assessment of resources depletion and a more in-depth analysis of micro aspects
- TIMES provide LCA and ExternE equilibrium average commodities/ technologies mix and equilibrium prices and their dynamic evolution for different policy scenarios