Technology Learning in the ETP Model

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Topics

1. The Technology Learning Modelling Challenge
2. The ETP Experience
3. Case Study Renewables
4. Conclusions

1 The Technology Learning Modelling Challenge

Issues

- Applicability of theory;
- Data uncertainty;
- Calculation efforts vs. policy relevance;
- Algorithm choice.

Basic Theory

Investment cost decline continuously with X % for each doubling of the cumulative capacity

Is This Theory Really Widely Accepted ?

Some statements:

- “All technologies have a PR of 0.82”;
- “Established technologies learn at a lower rate than emerging technologies”;
- “Learning rates will decline as the technology matures”;
- “Technology learning will require more R&D funds”;

Modelling creates new learning issues

- What about salvaging of learning
- What about regional spill-over effects
- What about learning-by-doing vs. learning by R&D
- What is a "correct" discount rate for learning investments
- What is a credible maximum industry growth rate

Data Uncertainty Example Fuel Cells: 0.7 *or 4.5 trillion US$ Needed?*

VEHICLE PRODUCTION	2020	2030	2040	2050
Cumulative FCVProduction, OECD (millions)	0.1	14.1	95	261.2
Cumulative FCV Production, World (millions)	0.1	14.7	113.7	404.3
FCV Share of Sales, OECD (%)	0.1	10	30	50
VEHICLE COSTS, OPTIMISTIC CASE				
Incremental cost per vehicle - 0.82 progress ratio ($)	13,000	3,300	1,850	1,300
Total FCV incremental cost ($ bln)	2	55	255	654
VEHICLE COSTS, PESSIMISTIC CASE				
Incremental cost per vehicle - 0.9 progress ratio ($)	34,000	16,400	12,000	9,900
Total FCV incremental cost ($ bln)	6	257	1,501	4,481

Source: IEA 2003

Strict Application of the Theory in an Energy Model

Can PV cost really decline by a factor 10?
Reality check needed

	2000	2010	2020	2030	2040	2050
Investment growth rate	20.0%	20.0%	20.0%	15.0%	15.0%	10.0%
Cumulative Capacity (GW)	0.3	2.1	13.0	65.3	264.2	685.3
Investment costs ($/kW)	5500	3058	1700	1012	646	475

Calculation Efforts vs. Policy Relevance

- **ETL can be of key importance;**
- **But calculation time multiplies with ETL;**
- **End point (2050) can look similar with ETL and endogenous investment cost reductions;**
- **Using ETL will result in higher initial investments 2000-2030;**
- **ETL is important if competition between learning technologies is analysed;**
- **ETL is less important if competing policy packages (picking winners) are analysed.**

MARKAL Algorithm Choice

- ETL:
  IC(t) = f(IC(t0),GROWTH,CCAP(t0),PR,Investmnt(t0…t))
- HETL:
  IC(t) = f(IC(t0),GROWTH,CCAP(t0),PR)
- IETL:
  IC(t) = f(IC(t0),GROWTH,CCAP(t0),PR,growth path)
- SETL:
  IC(t) = user defined, in combination with lower bound on investments
- HETL/IETL: code is available, not yet tested

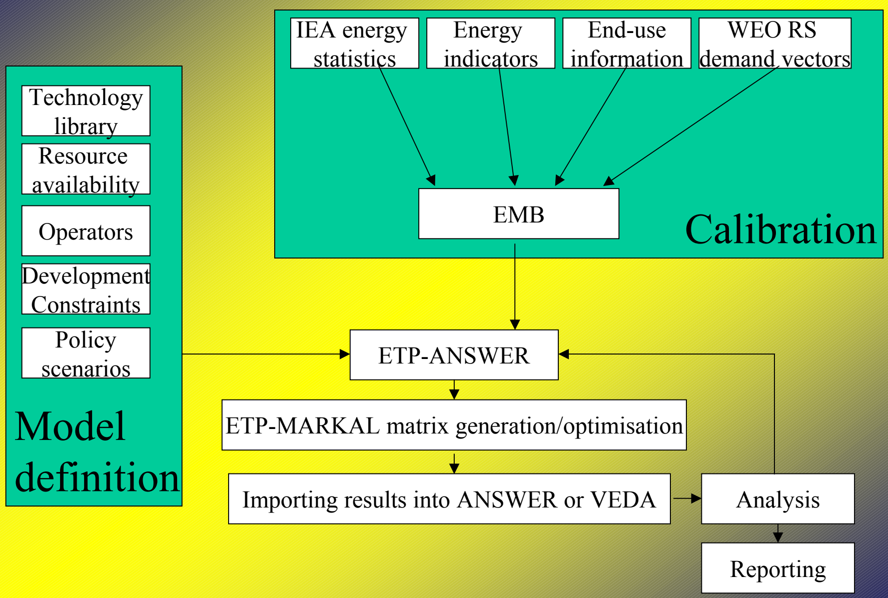
2 The ETP Experience

What is ETP ?

- Energy Technology Perspectives model;
- ANSWER-MARKAL based;
- Global, 15 regions;
- “From Well to Wheel”;
- So far applied for CCS, hydrogen, transport and renewables;

- IEA - ETP model takes 45 minutes to solve (2000-2050, 15 regions).

ETP model structure



ETP Technology Learning
“Uphill progress“

- ETL: works, but too slow for complex problems
- SETL: works, but interpretation is tricky
- IETL: code implemented, to be tested

3 Renewables Case Study (SETL)

Policy Questions

- Do we need investment subsidies forever?
- Will long-term benefits outweigh short-term cost?
- What about renewables – CO_2 capture competition?
- Can transfer of cheap renewables technologies (post learning phase) solve the CO_2 problem?

Deployment Policies

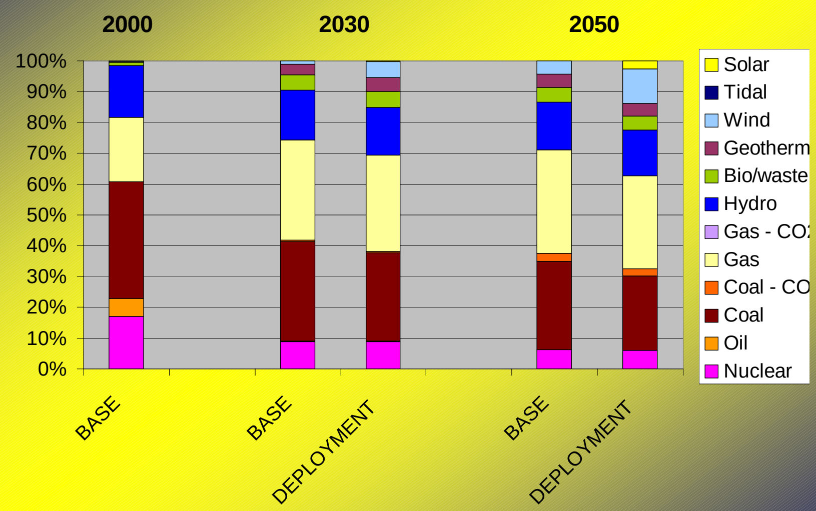
(Lower bounds in model terms)

Deployment targets [PJ/yr]				
	WEU	USA	Other IEA	Others
Small hydro	257.7	51.5	216.4	505.2
Biomass	468.3	622.5	287.9	546.3
Geothermal	46.4	140	56.3	281.7
Wind	3026.2	509.5	100.3	493.8
Solar	16.7	109.8	13.9	26.2
Tidal	47.3	9.5	0.3	3

Investment Cost Reductions

	Learning rate		Investment cost ($/kW)					
			DEPLOYMENT			BASE		
		2000	2010	2020	2050	2010	2020	2050
Wind onshore	10%	1000	785	576	434	836	788	689
Solar PV	20%	5500	3004	1545	848	3767	2987	2046
Solar thermal	5%	2400	2089	1792	1562	2200	2086	1912
Geothermal	5%	1250	1206	1154	1040	1223	1196	1121
Small hydro	5%	2500	2448	2392	2240	2464	2428	2323
Bio IGCC	10%	-	2500	2261	1710	2500	2390	2089
Tidal	5%	3200	2858	2503	2181	3034	2968	2780

Impact on Power Sector Fuel Mix



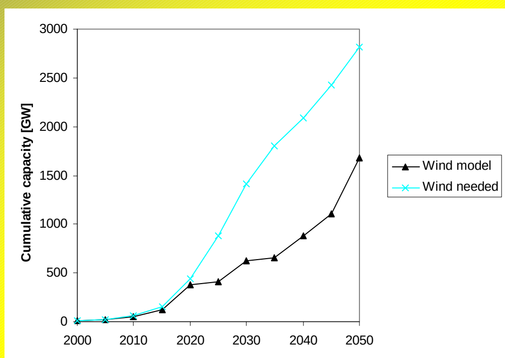
Consistency Check:

Wind seems ok, given data uncertainty

		2000	2010	2020	2030	2040	2050
Wind	Assumed capacity doublings		2.3	5.2	6.9	7.5	7.9
	Model capacity doublings		2.1	5.0	5.7	6.2	7.2
	Assumed investment cost index [-]	100	78	58	48	45	43
	Model implicit investment cost index [-]	100	80	59	55	52	47
PV	Assumed capacity doublings		2.7	5.7	7.4	8.0	8.4
	Model capacity doublings		2.1	4.9	4.9	9.4	11.4
	Assumed investment cost index [-]	100	55	28	19	17	15
	Model implicit investment cost index [-]	100	63	33	33	12	8
	Model implicit investment cost index PR = .83 [-]	100	68	40	40	17	12

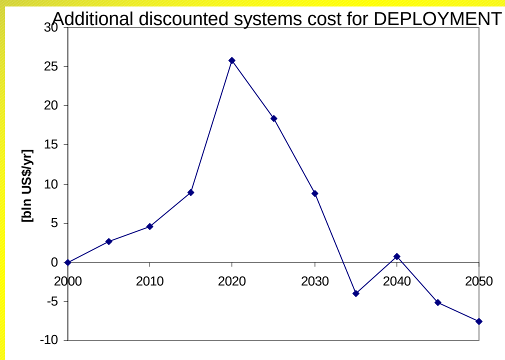
Consistency Check:

Investments continue post-2020: The Market Forces take over from Policy Initiatives



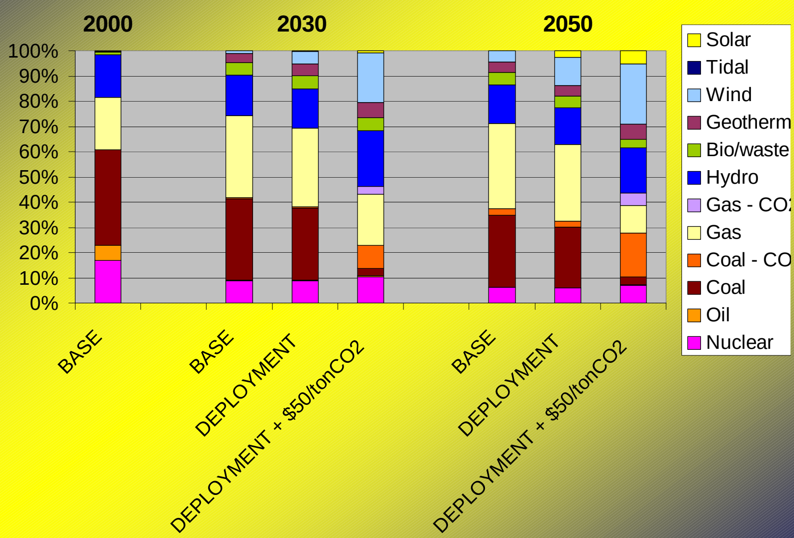
Policy Cost-Effectiveness

Not cost-effective pre-2050 (excluding CO_2 externalities): technology transfer alone is insufficient



DEPLOYMENT + CO2 Tax

Renewables and CCS are both needed



4 Conclusions

Conclusions so far

- New technology and technology learning is a key policy issue;
- Especially relevant for certain emerging technologies;
- Modelling of learning still under development;
- The relevance of endogenous learning depends on the type of policy analysis.

Outlook

- Test IETL
- Reality check of cost reductions via learning
- Learning by R&D vs learning-by-doing
- Spill over effects/technology transfer
- Focus on fuel cells/solar