Modeling for Energy Future: Econometric and Backcasting

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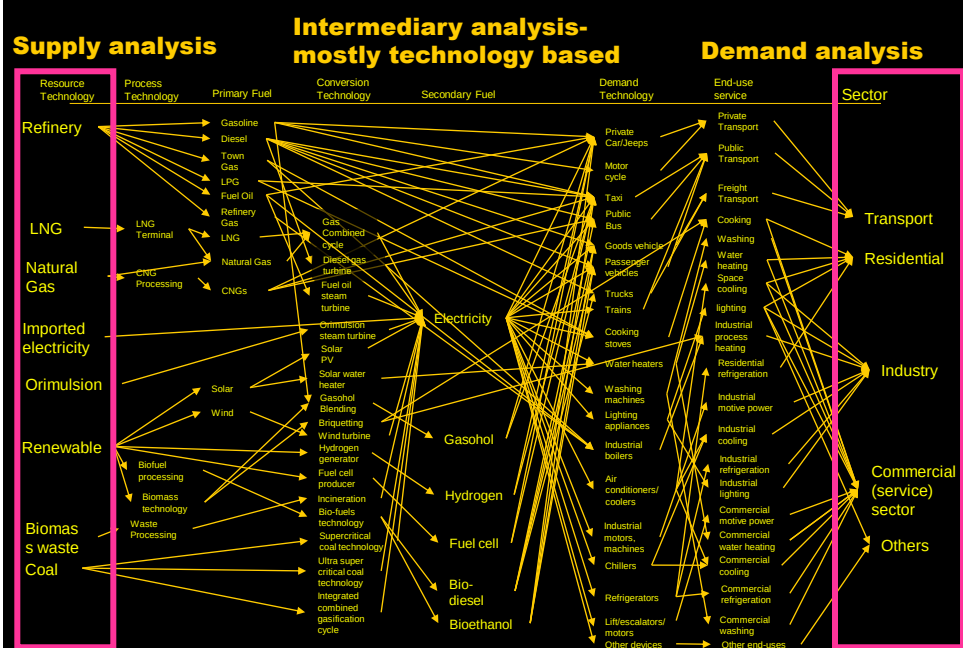
Various methods..

- **End-use based**
  - SEAM- Service Energy Analysis Model - good for individual end-use analysis- Techno-microeconomic base model
  - MEDEE – large scale database oriented end-use energy analysis model
  - IREDSS
    - Multiobjective method and GIS
      - Excellent for Local level energy planning and constrained by the use of GIS
  - MARKAL..
  - Generic models such as econometric

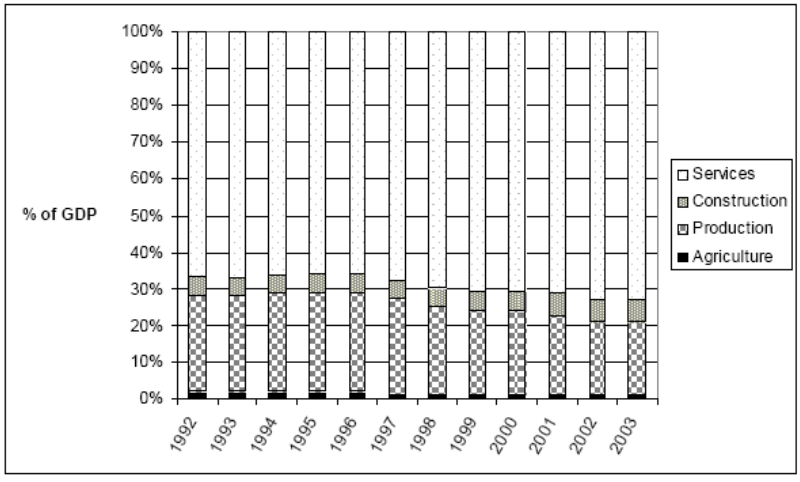
Suitability of model depends on the goal of modeling, data and software availability and competence of the modeler.

Possibilities have to be understood.. Present and future



Changing economic structure

Figure 5. Changing composition of UK GDP: 1992-2003



Source: Office of National Statistics (2005d)

http://www.sml.hw.ac.uk/logistics/Decoupling_of_Road-tonne-km_and_GDP.pdf

Econometric model

- **Inclusion of parameters is based on a country's socio-economic situation**
  - population,
  - stretch of road (KM extension),
  - number of vehicles,
  - number of houses built,
  - economic performance of the country, and
  - family income.
- **Based on time series data of actual consumption.**
  - The best model fits the actual consumption.
  - The projection is based on the status of parameters assumed for the future.

Projections have been done for many years..

Econometric model

- **The model exhibits dependency**
  - Interdependency among the chosen variables
  - Fit of some of the independent variables on dependent variables
  - Dependency on the scale of variables

$$y = ax_1^{\,b} x_2^{c}$$

Example on Transport Sector

Year	Transport Energy		Urban Pop	Vehicle numbers	Transport GDP	Diesel Price	Petrol price	ATF Price
1	116		1590	65887	7917	7500	12900	4365
2	110		1627	76378	8759	9100	12900	13260
3	157		1680	87902	9910	10000	20000	13260
4	188		1797	102369	10772	10000	25000	15570
5	211		1921	115230	11597	11500	29000	16655
6	227		2055	131839	12653	12000	29000	16655
7	262		2198	149253	13995	12000	29000	19300
8	291		2350	172446	14759	13500	31000	19300
9	307		2513	191556	15902	14000	34000	21744
10	349		2688	211981	17186	15500	39000	23532
11	369		2874	236120	18355	15500	40000	23532
12	373		3074	264400	19644	23000	40000	28800
13	396		3288	305395	20860	26500	46000	28800
14	351		3315	354955	21201	26500	52000	28800
15	372		3390	391750	22021	31000	54000	33000

For general model, look at the numbers… four to six digits

Transportation –Log Model

LOG MODEL							
Transport Energy			Urban Pop	Vehicle numbers	Transport GDP	Diesel price	Petrol price	ATF Price
4.76			7.37	11.10	8.98	8.92	9.46	8.38
4.70			7.39	11.24	9.08	9.12	9.46	9.49
5.06			7.43	11.38	9.20	9.21	9.90	9.49
5.24			7.49	11.54	9.28	9.21	10.13	9.65
5.35			7.56	11.65	9.36	9.35	10.28	9.72
5.42			7.63	11.79	9.45	9.39	10.28	9.72
5.57			7.70	11.91	9.55	9.39	10.28	9.87
5.67			7.76	12.06	9.60	9.51	10.34	9.87
5.73			7.83	12.16	9.67	9.55	10.43	9.99
5.86			7.90	12.26	9.75	9.65	10.57	10.07
5.91			7.96	12.37	9.82	9.65	10.60	10.07
5.92			8.03	12.49	9.89	10.04	10.60	10.27
5.98			8.10	12.63	9.95	10.18	10.74	10.27
5.86			8.11	12.78	9.96	10.18	10.86	10.27
5.92			8.13	12.88	10.00	10.34	10.90	10.40

One shot models may not be suitable

Model with actual values

	Regression Statistics					
	Multiple R	0.996493				
	R Square	0.992998				
	Adjusted R	0.987747				
	Standard E	10.87843				
	Observatio	15				
	ANOVA					
		df	*SS*	*MS*	*F*	*Significance F*
	Regressior	Between 6	134266.8	22377.79	189.0972	3.56469E-08
	Residual	Within 8	946.7212	118.3402		
	Total	14	135213.5			
		Coefficients	*tandard Err*	*t Stat*	*P-value*	*Lower 95%*
	Intercept	-145.291	49.25977	-2.94948	0.01844	-258.8839452
URBAN	X Variable	-0.02018	0.10839	-0.18622	0.85691	-0.270131613
VEHICLE	X Variable	-0.00093	0.000263	-3.52362	0.007804	-0.001535251
T_GDP	X Variable	0.044122	0.017725	2.489223	0.037568	0.003247632
D_PRICE	X Variable	-0.00062	0.002469	-0.25129	0.807925	-0.006314008
P_PRICE	X Variable	0.001294	0.001529	0.845926	0.422174	-0.002232641
A_PRICE	X Variable	-0.0026	0.002561	-1.01578	0.339468	-0.008508491

Critical F = 3.58
Critical t= 2.145

Min req.

P values can also be used

Log Model

	Regression Statistics					
	Multiple R	0.9975955				
	R Square	0.9951967				
	Adjusted R	0.9915942				
	Standard E	0.0392419				
	Observatior	15				
	ANOVA					
		df	*SS*	*MS*	*F*	*Significance F*
	Regression	6	2.55247	0.42541	276.254	7.92323E-09
	Residual	8	0.01232	0.00154		
	Total	14	2.56479			
		Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*
	Intercept	-10.329366	0.97479	-10.597	5.5E-06	-12.57722849
urban pop	X Variable	-0.5648835	0.84612	-0.6676	0.52316	-2.516029175
number	X Variable	-0.931048	0.27687	-3.3628	0.00989	-1.569510834
TrnsGDP	X Variable	3.2782832	0.79423	4.12764	0.00331	1.446793086
Diese	X Variable	-0.1565943	0.13661	-1.1463	0.28481	-0.471621861
Petrol	X Variable	0.3195938	0.15222	2.09961	0.06898	-0.031416915
ATF	X Variable	-0.1765716	0.09543	-1.8502	0.10144	-0.396640765

Critical F = 3.58
Critical t= 2.145

Improved log model

	Regression Statistics					
	Multiple R	0.9889749				
	R Square	0.9780714				
	Adjusted R	0.9744167				
	Standard E	0.0684605				
	Observatior	15				
	ANOVA					
		df	*SS*	*MS*	*F*	*Significance F*
	Regression	2	2.50855	1.25427	267.616	1.11189E-10
	Residual	12	0.05624	0.00469		
	Total	14	2.56479			
		Coefficients	*andard Er*	*t Stat*	*P-value*	*Lower 95%*
	Intercept	-11.367951	1.26635	-8.977	1.1E-06	-14.12708465
Number	X Variable	-1.2514942	0.29041	-4.3093	0.00102	-1.884254064
GDP	X Variable 2	3.3376525	0.48823	6.83622	1.8E-05	2.273889385

Critical F = 3.89
Critical t= 2.145

Therefore, one shot models by looking at R-squared may not give a good picture
But is this a good model? It fits well.. Because it looks at the past

Viable econometric models

Summary of the models developed by (a) fuel type and (b) consumption sector

Model (in ln)	Fuelwood	Kerosene	LPG	Petrol	HSD	ATF	Electricity	Coal
(a)								
Intercept	−3.23	−60.134	−28.465	−6.371	−4.147	−2.35	−5.7662	−17.175
Rural pop	+1.206	+6.247						
Urban pop			+1.661				1.290	
GDP_trade		+0.728	+1.351					
Ind_GDP								+2.619
Agr_GDP								
Ker_price		−0.370						
LPG_price			+0.536					
HSD_price					−0.568			
Vehicles on petrol				+0.807				
Vehicles on diesel					1.383			
Airline passengers						0.786		
Correlation coefficient	0.998	0.987	0.983	0.975	0.958	0.76	0.909	55%

Model (in ln)	Residential	Industrial	Transport	Service	Agriculture
(b)					
Intercept	−1.561	−5.247	−2.579	−10.999	−50.104
Rural pop	+0.946				
Urban pop	+0.164				
Service_GPD				+1.335	
Agr_GDP					+4.698
Private consumption	**−0.021**	**+0.875**			
Total vehicles			**+1.329**		
Diesel_price			**−0.821**		
Correlation coefficient	**0.999**	**0.805**	**0.927**	**0.930**	**0.919**

Do they match?

An econometric analysis of energy consumption in Nepal
Energy Policy, Volume 35, Issue 1, January 2007, Pages 350-361
Shaligram Pokharel

Assuming everything goes well

	Based on scenario 1	
Type	2007	2012
Fuelwood	7156 (80.0%)	7941 (71.32%)
Petroleum	1353 (15.1%)	2405 (21.59%)
LPG	275	732
Kerosene	522	864
MS petrol	66	96
HSD	436	638
ATF	54	75
Coal	286 (3.2%)	573 (5.15%)
Electricity	156 (1.7%)	216 (1.94%)
Total	8951	11135
Residential	8328 (85.2%)	9312 (81.3%)
Industrial	612 (6.3%)	982 (8.6%)
Transportation	531 (5.4%)	667 (5.8%)
Service	135 (1.4%)	189 (1.6%)
Agriculture	166 (1.7%)	308 (2.7%)
Total	9772	11458

For fuel projection

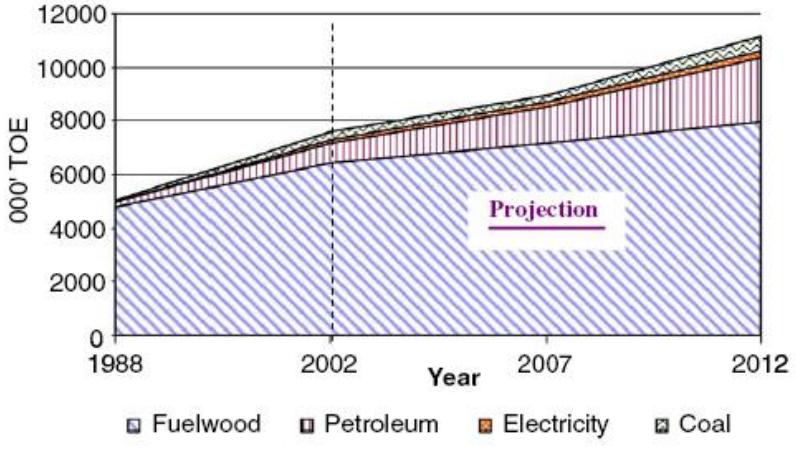
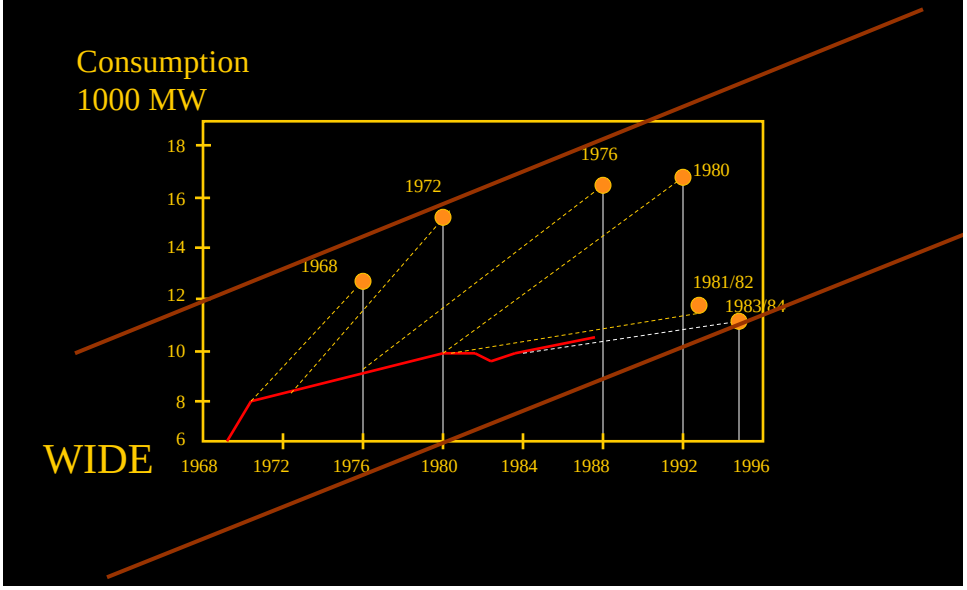


Fig. 1. Consumption and projection of energy requirements under Scenario 1.

National Electricity Demand Forecasts for the Netherlands



Backcasting!

- **Energy is a dependent outcome**
- **Need to develop alternative paths on other sectors like climate**
  - future in terms of technology and in terms of economic structure?
  - for example, should it be designed based on GHG targets

Should we consider new fuels?

1	Biofuel technologies	Biodiesel	
		Bioethanol	
2	Clean-coal technologies	Supercritical	
		Ultra-supercritical	
		Integrated Gasification Combined Cycle (IGCC)	Includes pre-capture, post-capture and sequestration
3	Fuel type for power generation	Coal-biomass	Biomass materials include palm oil kernel
		Pyrolsis fuel oil with coal	
		Orimulsion	
		Food Waste	IUT Global (food waste to energy) [IE]
		Incineration Waste	
		Wood Chips	Eco-Wise (wood waste to energy) [IE]
		Fuel Oil	
		Natural Gas (PNG, LNG)	
		Dimethyl Ether	Itochu Corporation exploring the import of DME [EDB]
		Electricity Import	Possibly from other countries in ASEAN, restrict to 200 MW. Model shd have
4	Renewables	Solar PV	Includes concentrating solar and solar PV thin-film and silicon-based, and building-
		Solar thermal	
		Micro-hydro	Atlantis International
		Wind	

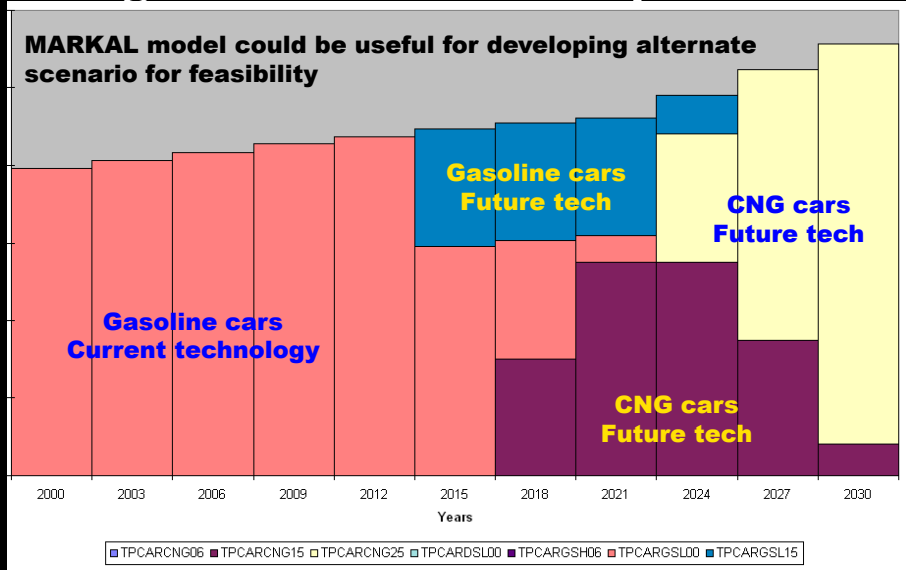
What about improvements in technology?

- **What about the learning rate of technology?**
  - In terms of efficiency
    - Efficiency of refrigerator has doubled in ten years.
  - In terms of cost
    - The cost of refrigerator has reduced by almost one quarter
- **For example cars**

	Efficiency	OM cost	First cost	
Gasoline Car ICE 2000				
TPCARGSL00				
TPCARGSL15	106%	100%		102%
TPCARGSL25	111%	100%		102%
Diesel Car ICE 2000				
TPCARDSL00				
TPCARDSL15	103%	100%		103%
TPCARDSL25	114%	100%		103%
Car E 85 Flex-Ethanol ICE 2015				
TPCARE8515				
TPCARE8525	106%	100%		102%
Car CNG 2006				
TPCARCNG06				
TPCARCNG15	104%	87%		86%
TPCARCNG25	104%	97%		97%
Car Hybrid Gasoline ICE 2005				
TPCARGSH05				
TPCARGSH15	113%	89%		87%
TPCA				
Car E				
TPCA				
TPCARDSL15				
Car Hydrogen ICE 2021				
TPCARHYD21	109%	92%		98%

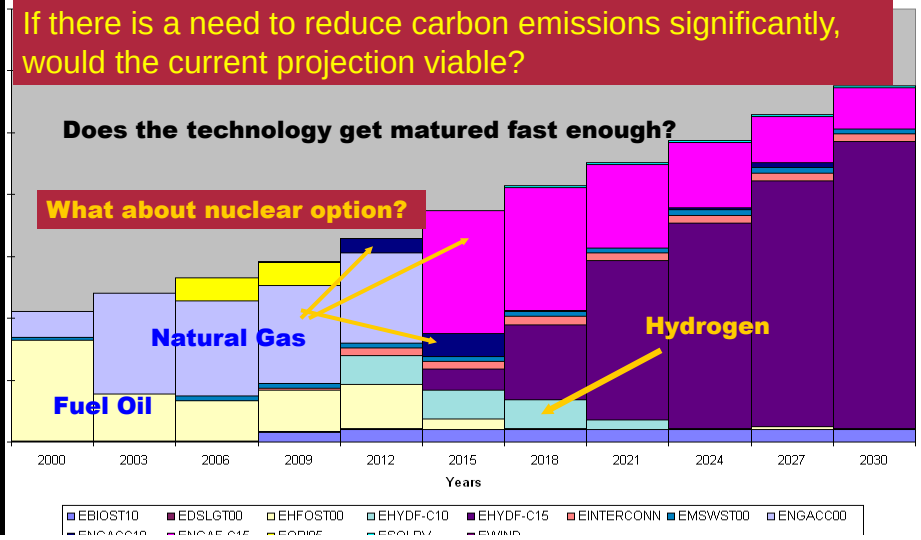
Assumptions only
Planners have to depend on domain experts

What would be the impact of changes in fuel availability as well?



What if there is a need for carbon-clean technology?

If there is a need to reduce carbon emissions significantly, would the current projection viable?



Other questions to answer

- How fast are the new technologies coming up?
- What would be the cost of new technologies?
- How fast are the new technologies penetrating the market?
- How fast these technologies replace the old technologies?
- What about urbanization?
- What about opportunity to supply new technology?

- These questions are not answered by Econometric models

Extrapolation to 2030- econometric model

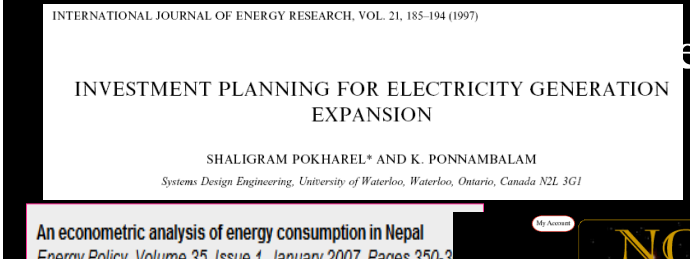
Sectors	Energy ('000 TOE)	Share	Growth rates 2002-2030 Energy
Industrial	6532	28.9%	9.78%
Residential	13071	57.7%	2.04%
Transportation	2077	9.2%	7.23%
Service	760	3.4%	7.40%
Agriculture	201	0.9%	3.35%
Total	22640		3.61%

Energy with backcasting

Fuel\ Sectors	Residential	Industrial	Transport	Service	Agriculture	Total	Share	Annual growth rate from 2002
Fuelwood	3514.8	113.2				3628.0	25.1%	-2.01%
Kerosene	36.5	746.4		272.6		1055.5	7.3%	4.64%
LPG	1160.0					1160.0	8.0%	8.92%
Petrol			341.6			341.6	2.4%	6.88%
Diesel		1789.4	1160.4		36.1	2985.8	20.7%	9.01%
ATF			328.2			328.2	2.3%	7.32%
Coal		1972.5				1972.5	13.7%	6.72%
Electricity	1096.9	1353.1	68.3	280.0	160.5	2958.7	20.5%	11.95%
Total	5808.2	5974.6	1898.4	552.6	196.6	14430.4		1.95%
Share	40.2%	41.4%	13.2%	3.8%	1.4%			
Annual growth from 2002	-0.88%	9.43%	6.89%	6.19%	3.27%	1.95%		

So finally,

- **Energy modeling is an important aspect in large scale planning**
- **Various methods can be used**
  - Micro methods are good for techno-economic analysis
  - Macro methods like econometric modeling is good for national level planning
  - Understanding the changes in energy pattern can be understood through Econometric models
  - Backcasting might be easier and better if we have more plausible data on domain based projection.



INTERNATIONAL JOURNAL OF ENERGY RESEARCH, VOL. 21, 185–194 (1997)

INVESTMENT PLANNING FOR ELECTRICITY GENERATION EXPANSION

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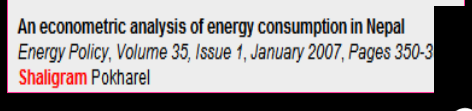

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Kyoto protocol and Nepal's energy sector

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Received 21 June 2006; accepted 22 September 2006
Available online 9 November 2006

Thanks!