REAL ENVIRONMENTAL SWITCHING OPTIONS

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DURHAM WORKSHOP JULY 2023

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- "By far the greater part of what we hold might be allowed to perish at any moment, without harm, if we could have it re-created with equal ease at a future moment, when need of it arises“. *Theory of Political Economy, 1871.*

- Real Environmental Options in 1871

REAL ENVIRONMENTAL OPTIONS

- Real option methods - required for realistic, sensible environmental economics and policy evaluation.
- Implementing - defining the underlying focus and social costs, mathematical complexity for realism, and calibrating environmental measures.
- Switching Options: closing polluting generating facilities (coal), opening less polluting (renewables): input/input switching

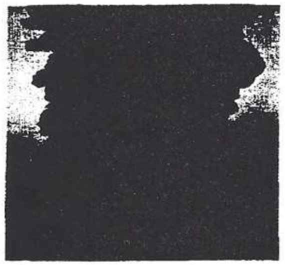
Nothing I have written has created more inquiries than one page in RISK magazine citing my uncompleted paper on Real Environmental Options in 1997.

Environmental option

With risk management growing to cover every contingency, how long before commodity markets choose to focus on environmental risk? **Nicholas Dunbar** has the answers

Over recent years, several leading multinationals sold a large number of barrier options to retail buyers. This year, the options unexpectedly knocked in and are now deeply in the money, leaving the multinationals offering high premiums to buy the options back. So who bought these options?

The answer: smokers, who unknowingly bought them with the cigarettes they bought from US tobac-



Disaster! Or is it?

approach to the problem can be found in a paper by Dean Paxson of Manchester Business School: "Ownership of undeveloped land is akin to owning an option to exploit the land's resources in the future, with present value linked to commodity prices. Real options are now an accepted route to pricing assets such as seabed drilling rights and oil/gas platforms."

But the same assets also have environmental

water demand and supply, or flexible versus inflexible storage costs."

For a power station, the equivalent underlying would be the costs of controlling specific air-water-land pollution: "Such figures are often given in power companies' responses to European directives. In the US, the existence of a market in pollution permits conducted by CBoT would make option calculations straightforward."

Questions from the Public about Real Environment Options

- “Where do we buy these options to put on our Green page?
- Can we trade the options?
- Who owns the patent?
- What do the options cover?
- Can we create more options?”

W. Stanley Jevons

- Input switching from horse, water to coal, WSJ believed was the secret to the British industrial revolution.
- Newcastle was the centre of this switching.

- WSJ “I see no prospect of any substitute being found for coal, as a source of motive power”.

- “There is no possibility of coal being replaced by wind in the U.K.”

- Now, Newcastle is the centre of switching to offshore wind

- *The Coal Question, 1865*

Switching Coal->??

- Coal "is the biggest source of greenhouse gases, making up more than 40% of energy-related carbon emissions in 2022" (*Economist* "Who is keeping coal alive?" 10 June 2023, p. 59)

- "Gas is 42.8% of total primary energy consumption in the UK" (HCEAC 12 December 2022, p. 36.)

- When to Switch, to What, RO of Switching
- UK Coal to Wood Pellets, NG to Renewables
- US Natural Gas, Renewables
- China ??
- India ?? Indonesia??

Coal >>CO_2

Table A13. World carbon dioxide emissions from coal use by region, Reference case

million metric tons carbon dioxide

Region	2020	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2020–2050
OECD								
OECD Americas	**969**	**843**	**808**	**759**	**727**	**710**	**716**	**-1.0**
United States	861	749	731	688	653	630	631	-1.0
Canada	48	47	26	18	19	20	21	-2.8
Mexico and other OECD Americas	60	48	50	53	56	60	64	0.2
OECD Europe	**766**	**672**	**586**	**596**	**622**	**618**	**633**	**-0.6**
OECD Asia	**800**	**802**	**800**	**832**	**839**	**801**	**760**	**-0.2**
Japan	393	437	427	452	452	413	368	-0.2
South Korea	259	261	280	290	301	305	311	0.6
Australia and New Zealand	148	104	93	90	86	83	81	-2.0
Total OECD	**2,536**	**2,317**	**2,194**	**2,187**	**2,188**	**2,129**	**2,110**	**-0.6**
Non-OECD								
Non-OECD Europe and Eurasia	**908**	**866**	**879**	**954**	**996**	**1,034**	**1,064**	**0.5**
Russia	471	493	504	556	571	580	583	0.7
Other Europe and Eurasia	437	374	375	398	426	453	481	0.3
Non-OECD Asia	**10,901**	**11,321**	**11,222**	**11,742**	**12,244**	**12,848**	**13,082**	**0.6**
China	8,578	8,279	7,736	7,594	7,469	7,380	7,304	-0.5
India	1,461	1,932	2,155	2,620	3,077	3,527	3,639	3.1
Other Asia	862	1,110	1,332	1,528	1,698	1,941	2,139	3.1
Middle East	**13**	**15**	**24**	**16**	**25**	**47**	**45**	**4.2**
Africa	**365**	**404**	**434**	**473**	**488**	**475**	**473**	**0.9**
Non-OECD Americas	**71**	**92**	**90**	**95**	**110**	**116**	**100**	**1.2**
Brazil	55	67	68	72	66	71	70	0.8
Other Non-OECD Americas	15	25	22	23	44	45	30	2.2
Total Non-OECD	**12,258**	**12,698**	**12,649**	**13,279**	**13,864**	**14,520**	**14,764**	**0.6**
Total World	**14,794**	**15,015**	**14,843**	**15,466**	**16,052**	**16,649**	**16,873**	**0.4**

Coal Consumption Projection

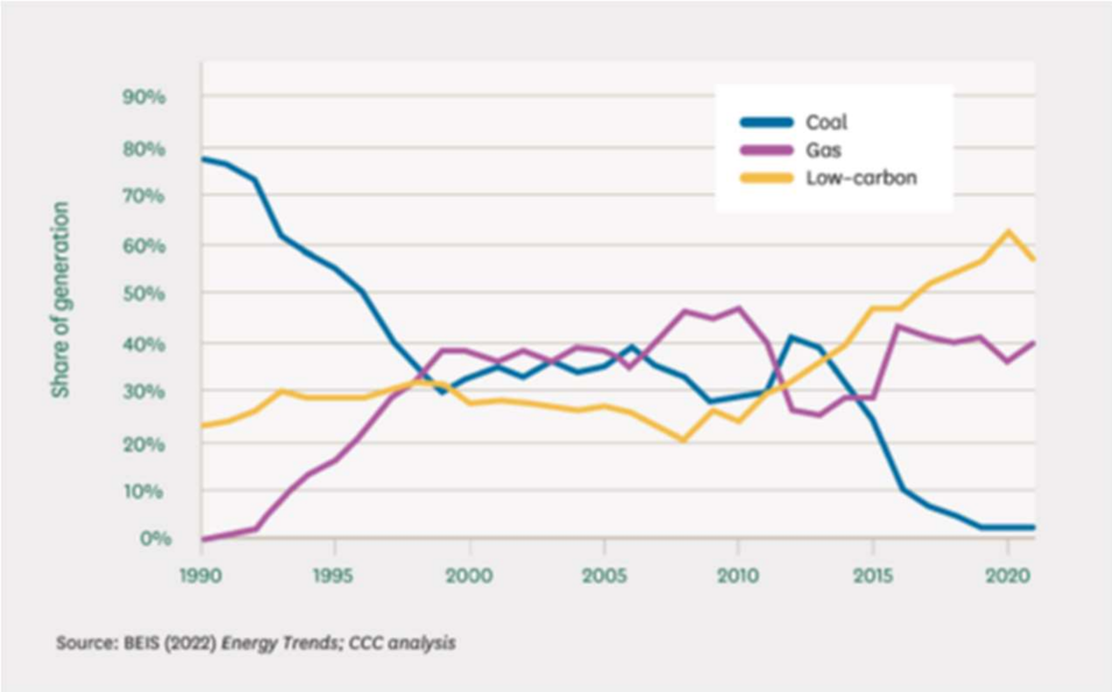
Table M5. World thermal coal consumption by region, Reference case

million short tons

Region	2020	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2020–2050
OECD								
United States	448	387	384	361	338	321	323	-1.1
Canada	23	21	8	2	3	3	3	-6.5
Mexico and other OECD Americas	23	15	15	15	15	17	17	-0.9
OECD Europe	465	370	298	301	318	310	317	-1.3
Japan	143	156	148	158	158	139	117	-0.7
South Korea	86	81	89	92	97	97	99	0.5
Australia and New Zealand	105	72	62	61	57	55	53	-2.3
Total OECD	**1,292**	**1,102**	**1,005**	**990**	**986**	**941**	**929**	**-1.1**
Non-OECD								
Russia	175	168	168	194	198	200	201	0.5
Other Non-OECD Europe/Eurasia	241	185	181	191	201	213	224	-0.2
China	3,700	3,585	3,365	3,373	3,384	3,402	3,422	-0.3
India	774	1,023	1,122	1,373	1,631	1,872	1,896	3.0
Other Non-OECD Asia	440	573	692	797	885	1,015	1,120	3.2
Middle East	1	2	6	1	5	15	14	8.1
Africa	185	204	219	238	245	237	234	0.8
Brazil	11	13	11	12	9	11	11	0.1
Other Non-OECD Americas	5	9	8	8	17	17	10	2.2
Total Non-OECD	**5,533**	**5,761**	**5,772**	**6,187**	**6,575**	**6,982**	**7,133**	**0.9**
Total World	**6,824**	**6,863**	**6,777**	**7,176**	**7,560**	**7,923**	**8,062**	**0.6**

DRAX 12% UK Generation from Wood Pellets replacing Coal

UK Generation Mix: Switch from NG to Wind/Solar



- ❑ 40% - Renewables
- ❑ 15% - Nuclear
- ❑ 40% - Gas

- ❑ Second-by-second demand-supply balance
- ❑ System to operate securely and safely
- ❑ Different technologies perform different roles

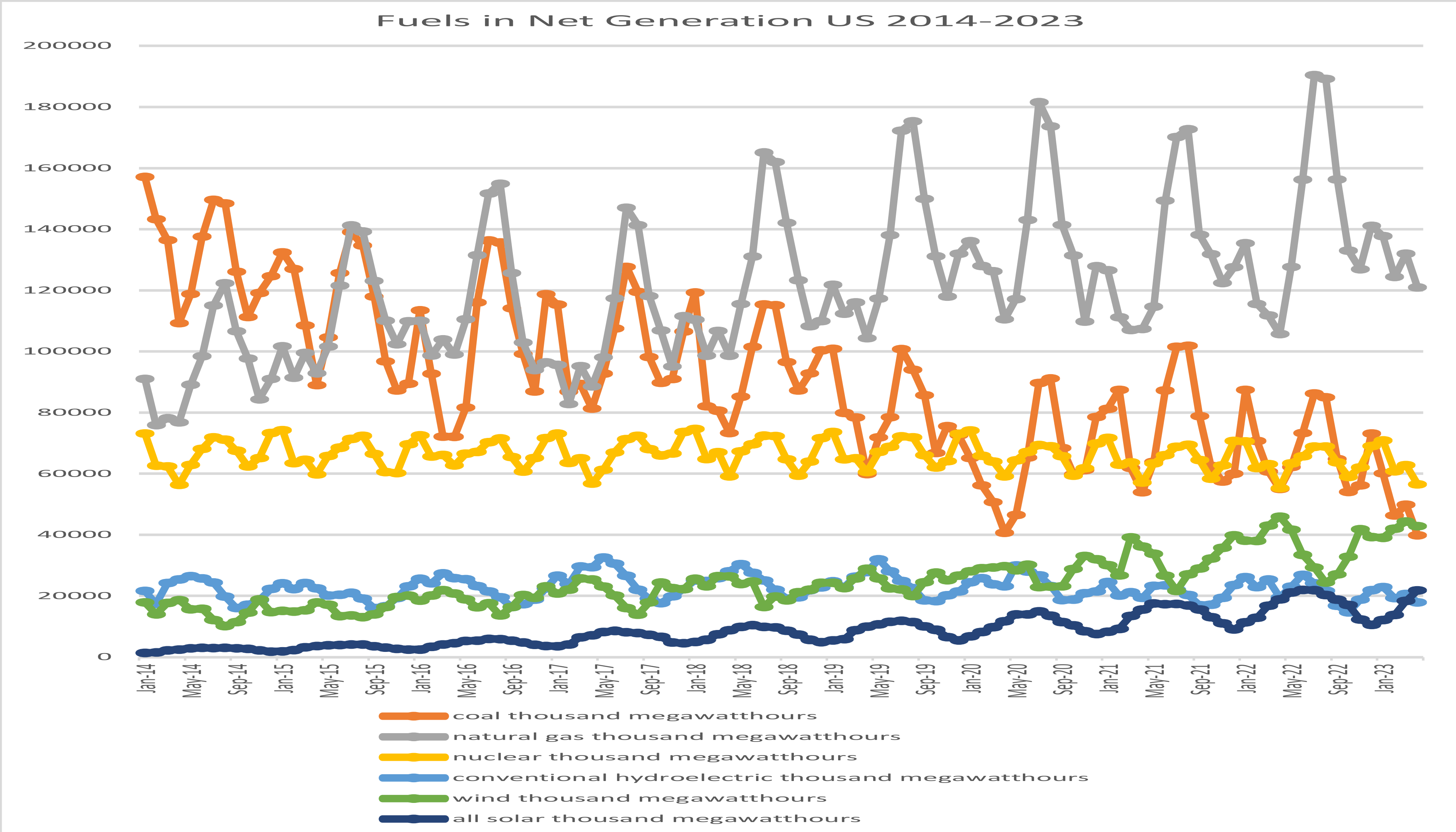
Coal switched to NG (US)

Table E3.gen. Electricity generation: United States, Reference case

billion kilowatthours

Fuel	2020	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2020–2050
Liquid fuels	16	10	9	8	8	6	6	-3.1
Natural gas	1,636	1,551	1,562	1,584	1,706	1,840	1,953	0.6
Coal	774	706	696	654	620	593	593	-0.9
Nuclear	785	745	630	609	595	599	594	-0.9
Renewables	850	1,324	1,578	1,794	1,942	2,104	2,312	3.4
Hydro	283	295	295	295	294	294	294	0.1
Wind	343	630	673	731	748	762	790	2.8
Geothermal	16	19	25	32	40	45	50	3.9
Solar	132	297	497	643	762	899	1,071	7.2
Other	76	83	87	94	99	104	108	1.2
Net generation to grid	4,061	4,336	4,475	4,650	4,871	5,142	5,458	1.0

Switching from Coal to NG
US 2014-2023



China 2020->2050

Table E13.gen. Electricity generation: China, Reference case

billion kilowatthours

Fuel	2020	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2020–2050
Liquid fuels	10	10	2	0	0	0	0	-14.3
Natural gas	267	535	693	716	743	782	803	3.7
Coal	4,313	3,991	3,556	3,556	3,556	3,556	3,556	-0.6
Nuclear	331	416	538	674	795	905	1,002	3.8
Renewables	1,973	2,990	3,660	4,190	4,853	5,513	5,869	3.7
Hydro	1,117	1,266	1,334	1,381	1,448	1,448	1,448	0.9
Wind	574	899	1,001	1,001	1,001	1,001	1,001	1.9
Geothermal	0	0	0	0	0	0	0	0.0
Solar	281	824	1,304	1,774	2,368	3,025	3,379	8.6
Other	0	1	21	34	37	39	41	--
Net generation to grid	6,893	7,942	8,449	9,135	9,947	10,756	11,230	1.6

India 2020->2050

Table E14.gen. Electricity generation: India, Reference case

billion kilowatthours

Fuel	2020	2025	2030	2035	2040	2045	2050	Average annual percentage change, 2020–2050
Liquid fuels	8	8	3	0	0	0	0	-15.3
Natural gas	90	73	73	61	51	43	43	-2.4
Coal	965	939	888	1,049	1,210	1,357	1,217	0.8
Nuclear	36	52	69	76	106	128	151	4.9
Renewables	332	882	1,510	2,028	2,565	3,279	4,325	8.9
Hydro	138	223	286	295	300	305	310	2.7
Wind	109	219	376	614	918	1,124	1,147	8.2
Geothermal	0	0	0	0	0	0	0	--
Solar	45	379	770	1,020	1,224	1,694	2,676	14.6
Other	40	61	78	99	123	155	192	5.4
Net generation to grid	1,431	1,953	2,542	3,215	3,933	4,807	5,737	4.7

RO Switching Models

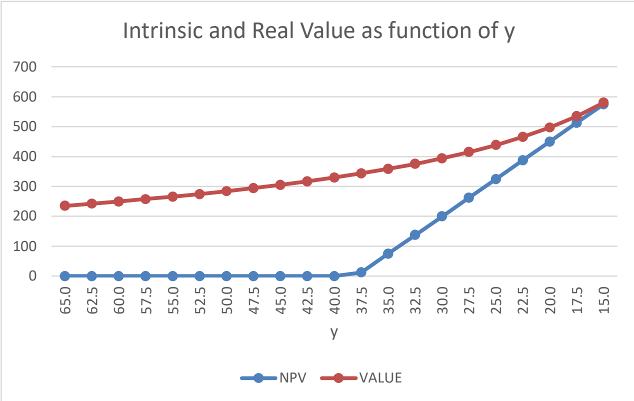
- INPUT SWITCHING C->WOOD UK
- maybe renewable, maybe lower CO_2
- INPUT SWITCHING C->NG US
- half CO_2, reliable source
- HIGH-LOW OPCOST NG->WIND, SOLAR UK
- high investment cost, low CO_2, quantity σ
- GLOBAL SWITCHING "DUOPOLY"
- EARLY SWITCHERS VS DELAYED SWITCHERS

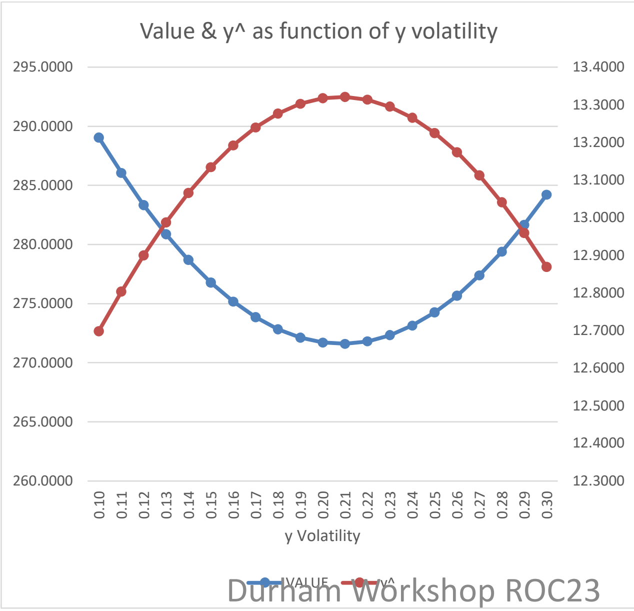
RO INPUT Switching Model

- INPUT SWITCHING C->WOOD UK
- maybe renewable, maybe lower CO_2
- INPUT SWITCHING C->NG US
- half CO_2, reliable source

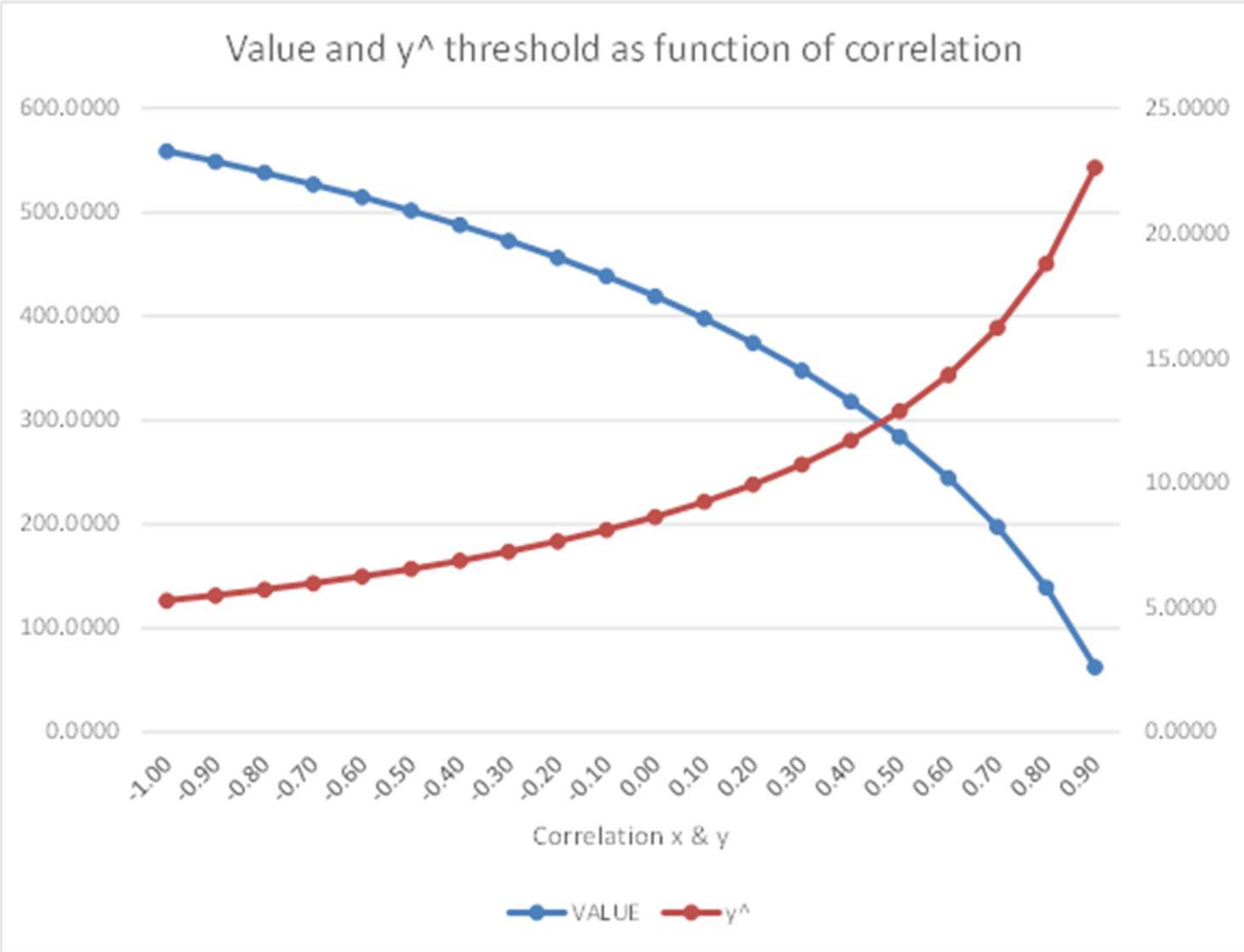
- Model Assumptions: Constant Input volatilities, yields and correlations
- (Adkins & Paxson, 2011, 2023)

Conclusions & Curiosities
INPUT Switching





Switching Model
Correlation of Inputs



RO Switching Models

- HIGH-LOW OPCOST NG->WIND, SOLAR UK
- high investment cost, low CO_2, quantity σ

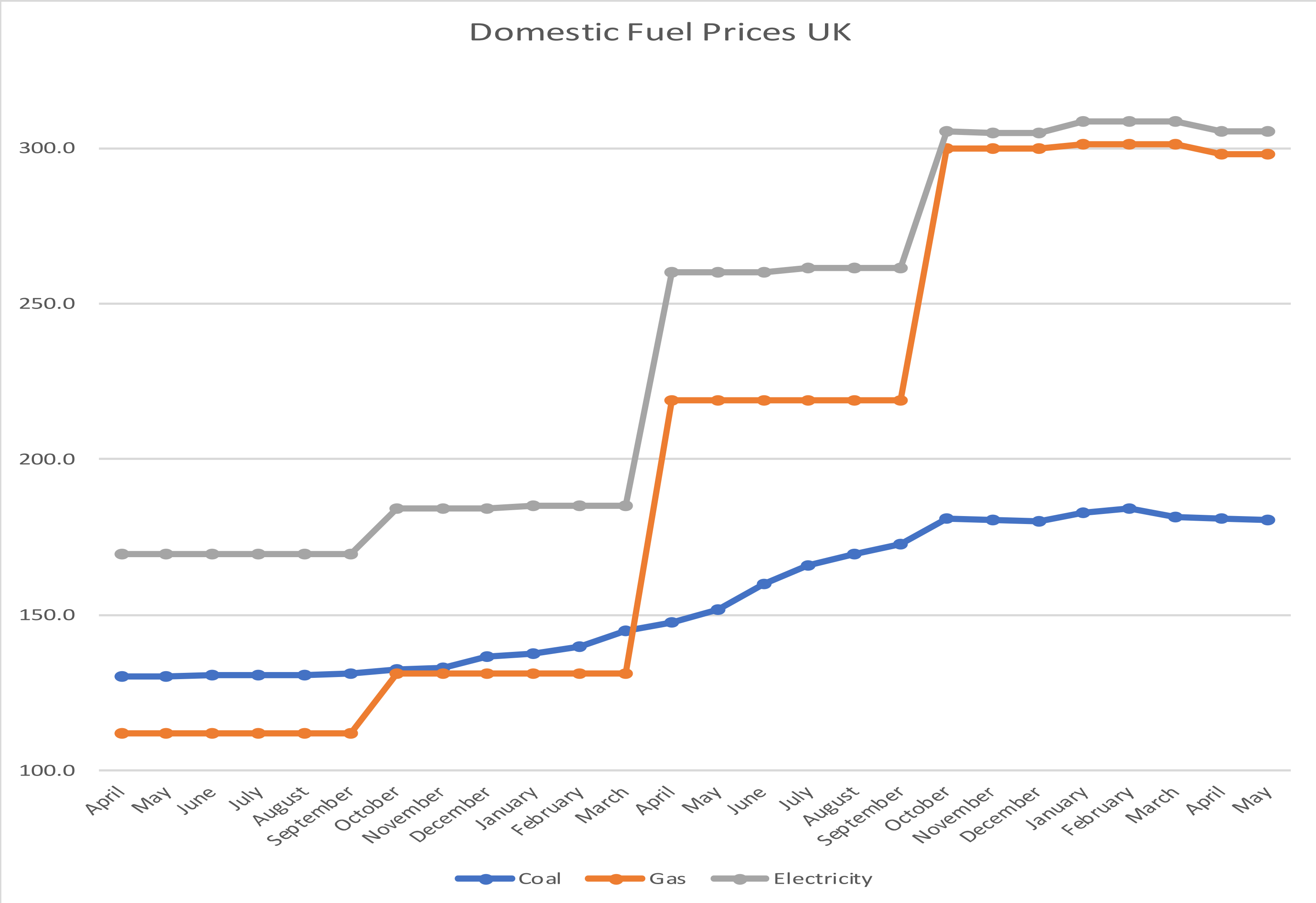
Dogger Bank Wind Farm (Newcastle)

See Roger Adkins presentation tomorrow

(NAO 2023)

Volatile UK Fuel Prices

		Coal	Gas	Electricity
MEAN	1990-2023	80.429	85.192	97.921
Stand Dev		36.990	51.292	52.237
MEAN	2021-2023	148.048	189.604	224.674
STDEV		33.324	83.698	70.670
Correlation			0.995	



RO Switching Models

- GLOBAL SWITCHING “DUOPOLY”
- EARLY SWITCHERS VS DELAYED SWITCHERS
- Suppose the early switchers = leaders, delayed=followers
- If there is eventually a global tax on CO_2 emissions, will leaders benefit?
- Adaptation of A, A & P (2022)

Global Ethics & Sustainability

- In the problem of the commons (think global climate control), what is a fair trade-off of economic growth benefit (per capita) vs. global emissions.

- How can the self-interest of nations be directed to global concerns? (see Midgley, 1996, "Sustainability and Moral Pluralism)

150 Years since Jevons

- What progress ?

- Real environmental option methodology is absolutely required for evaluating sensible economic policies regarding climate change, clean air, soil and water.
- We fall short on specific policy recommendations and specific threshold indications.

Progress since Jevons?

- Do we have good estimates on whether the environmental options left to future generations justify our current consumption and environmental policies?

- Do we provide an ambitious research agenda, involving combinations of environmental scientists and philosophers of global fairness & well-being?

Progress since Jevons?

- Consider more “realistic” real option models and imaginative solutions, working on global social cost measures (and possibly preferences and risk aversions for different participants in the real options games).

- Development of new RO models is interesting, and will eventually contribute to sensible and feasible environmental policies.

DUBS CASE STUDY 1 for CLIMATE CONTROL FINANCE & ECONOMICS CLASS

- **DOGGER BANK WIND FARM**
- Ex=ante and ex-post investment costs and operating costs
- NPV Model Projected Returns with/without CfD
- RO Model for Investment Opportunity
- Electricity price/quantity volatility estimate
- Electricity convenience yield
- Hedging Risk through CfD for SSE, for Gov + Customers

- Who wins, who loses as electricity & NG prices evolve?

DUBS CASE STUDY 2 for CLIMATE CONTROL FINANCE & ECONOMICS CLASS

- **KNOWNS, UNKNOWNS, TRANSPARENCY IN RENEWABLE SUPPORT SCHEMES**

- Contracts for Differences: Prices vs CO_2 Emissions
- NG Carbon Footprint by source (LNG 59 kgCO_2e/boe, 22 UK, 18 Norway)
- Offshore Wind (construction, operation, distribution, security, storage, profits)
- Who wins/who loses & who pays/when for kgCO_2e/boe reductions?

- **EVALUTION & TRANSPARENCY CSOL=BRITISH CUSTOMER**

- Terms of Contracts for Differences: Prices, Duration & Conditions
- Terms and Conditions of the CfD Supplier Obligation Levy CSOL
- Exposure to price, quantity, and timing (p, q, t) uncertainty?
- Calculation of Fair Value for CfD Portfolio ->CSOL->British Electricity Customer
- Is the CSOL contingent obligation a national debt?
- Is the CSOL offset an Electricity Customer debt?

- **TRANSPARENCY & DISCLOSURE OF CFD FOR SSE**

- Accounting for Contracts for Differences Exposure
- Hedging price, quantity, timing risk (during CfD, after termination)
- For DBWF
- Risk Exposure (to p.q.t) and K, op cost, kgCO_2e/boe regulation
- Renewable and NG mix evolution, and profitability

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Jevon’s paradox:

In economics, the Jevons paradox occurs when technological progress or government policy increases the efficiency with which a resource is used (reducing the amount necessary for any one use), but the falling cost of use increases its demand, increasing, rather than reducing, resource use. The Jevons effect is perhaps the most widely known paradox in environmental economics. However, governments and environmentalists generally assume that efficiency gains will lower resource consumption, ignoring the possibility of the effect arising.

In 1865, the English economist William Stanley Jevons observed that technological improvements that increased the efficiency of coal use led to the increased consumption of coal in a wide range of industries. He argued that, contrary to common intuition, technological progress could not be relied upon to reduce fuel consumption.