

The *4see* framework –
characterising an economy by its socio-economic
and energy activities

By Simon Roberts, Arup
(Foresight, Innovation and Incubation Group)

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Department of Civil Engineering
The University of Hong Kong

Your interests?

Collaboration of HK University with Arup?

- Specialisms:
 - economics, engineering, physical sciences, social sciences
- Does the 4see work fit with your:
 - school, discipline or straight interest/curiosity?
- Would a 4see project work as a:
 - student project
 - PhD project
 - peripheral activity
- Would research outcomes be:
 - publishable

Motivation of Arup and researchers

Current collaborators

- Simon Roberts: industrial physicist in Foresight Group, Arup.
- Colin Axon: School of Engineering and Design, Brunel University, London.
- Nigel Goddard: Institute for Adaptive and Neural Computation, School of Informatics, University of Edinburgh.
- Benjamin Warr: 10 years as Senior Research Fellow in Sustainability, INSEAD, Fontainebleau, France,
- Barney Foran: led research teams in Resource Futures group, CSIRO, Australia.

Our motivation

1. To make a contribution to low-carbon transitions and to sustainability
2. To advise, support and influence government policy
3. To apply research rigor

- *Australian Sustainable Energy - Zero Carbon Australia Stationary Energy Plan (2010), 194 pages*
- “Comparing a range of micro and macroeconomic annual figures from the Australian economy”
- “Shows that the ZCA2020 investment of \$AU37 billion per year is not extraordinary when compared with other public or private spending”
- Eg alcohol, gambling and recreation

FIGURE 7.4
ZCA2020 Stationary Energy Plan capital cost compared to other economic activity

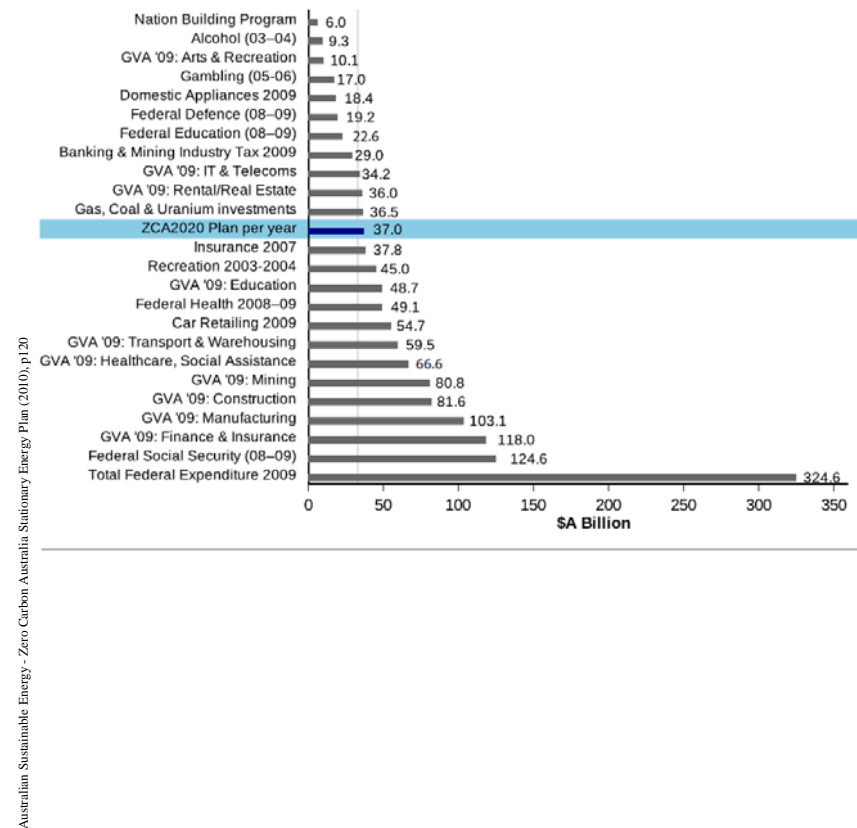
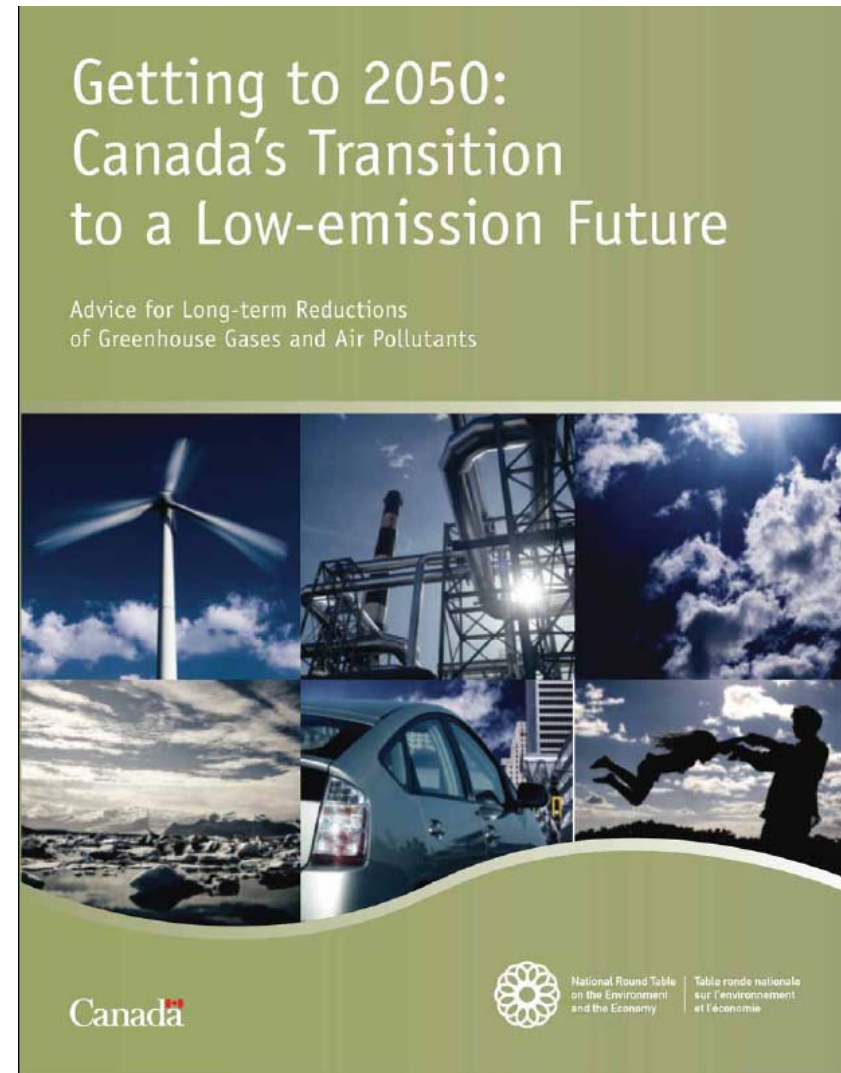


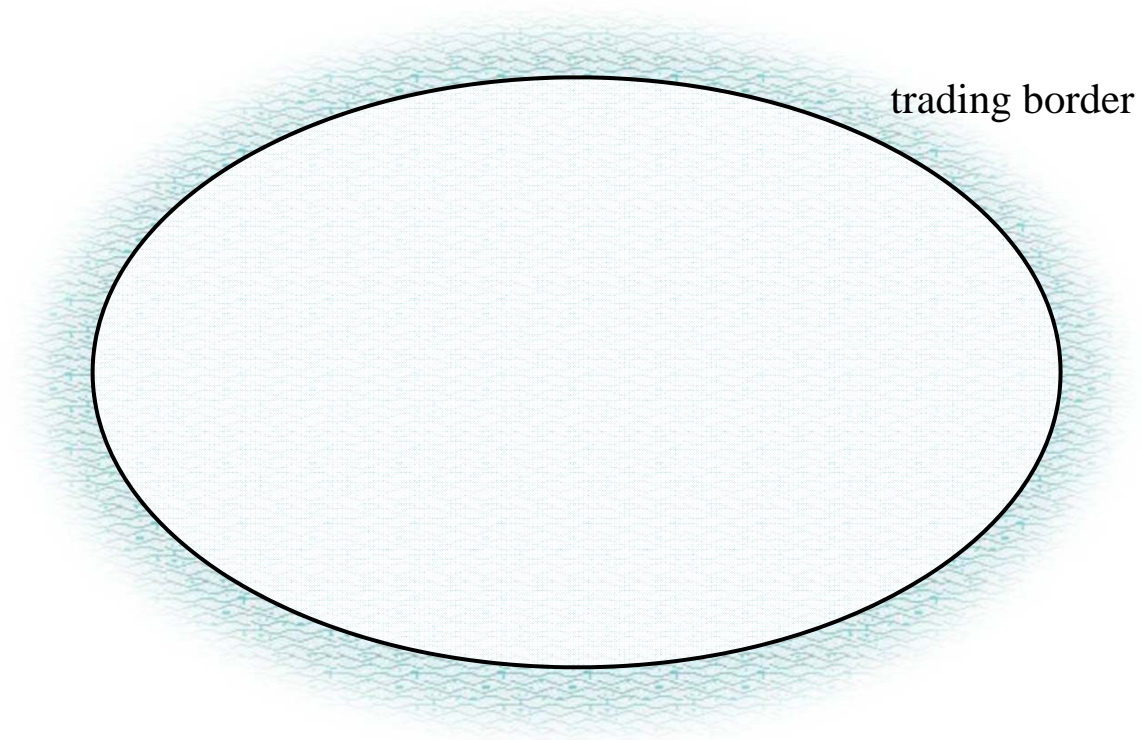
Figure 7.4 ZCA2020 Stationary Energy Plan capital cost compared to other economic activity

- *Getting to 2050: Canada's Transition to a Low-emission Future*, National Round Table on the Environment and the Economy (2007), 94 pages
- “Scenario assumption: In the policy scenarios an infinite amount of capital is available at the going interest rate”
- “(a commonly held assumption for Canadian Computable General Equilibrium models),”

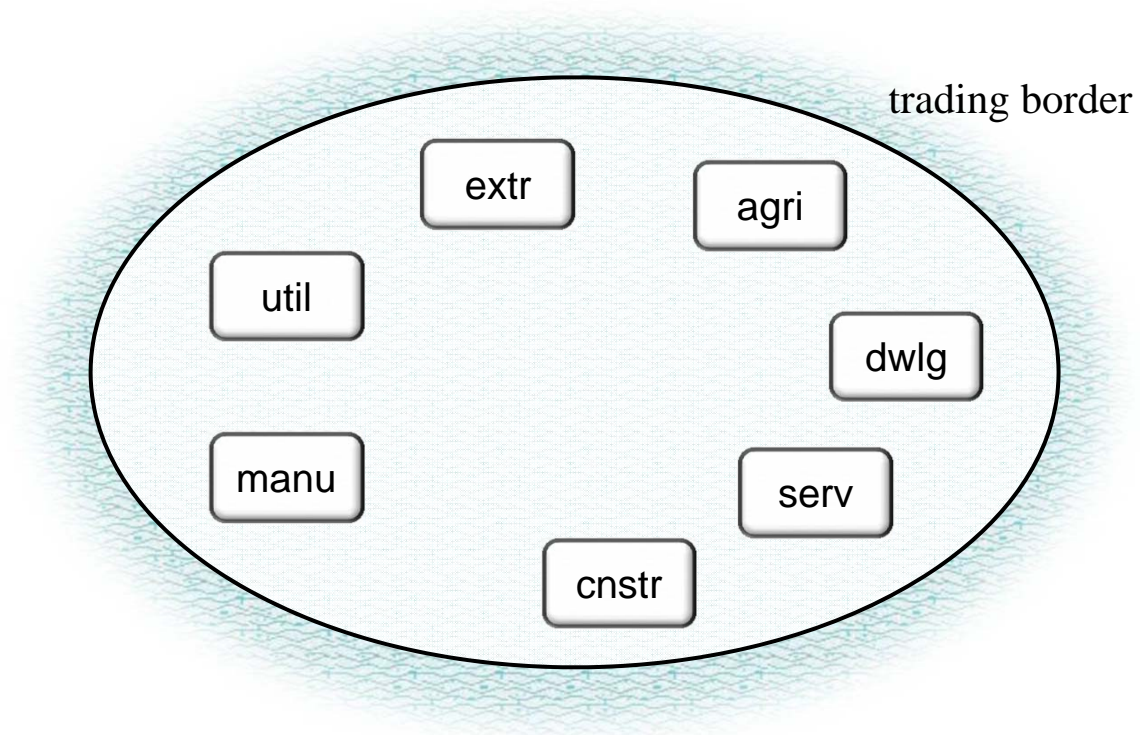


The *4see* approach

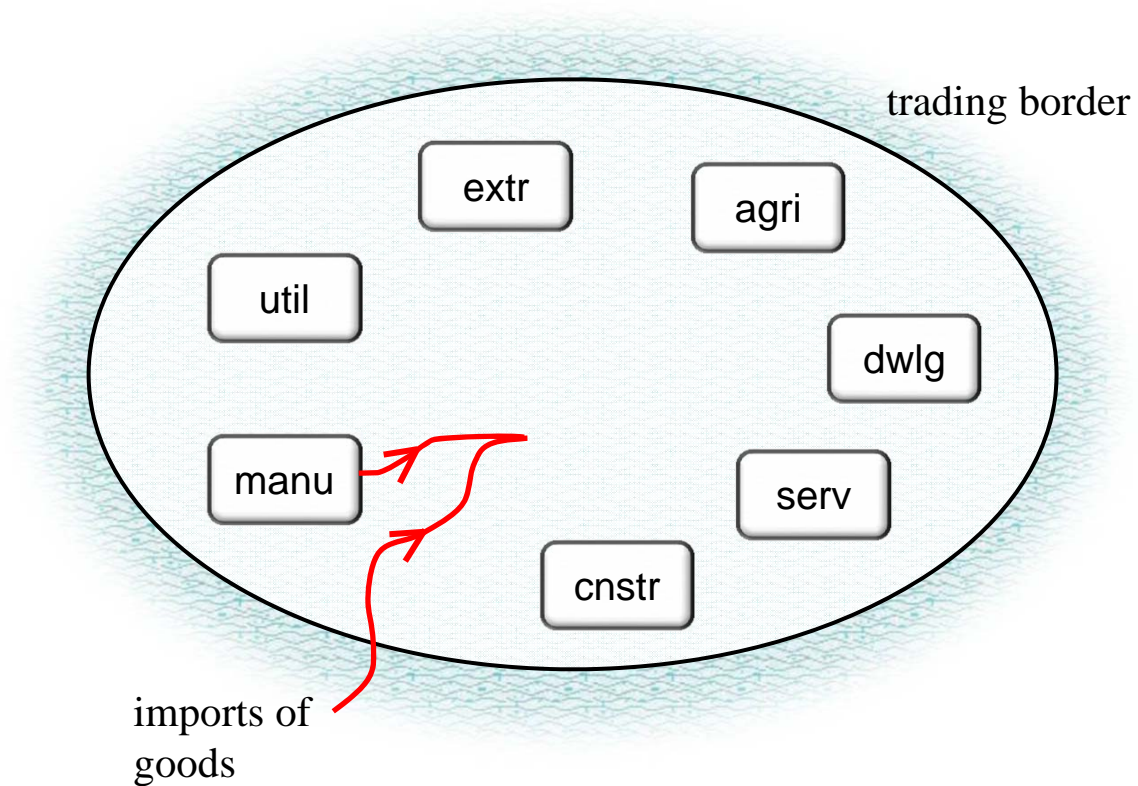
National scale



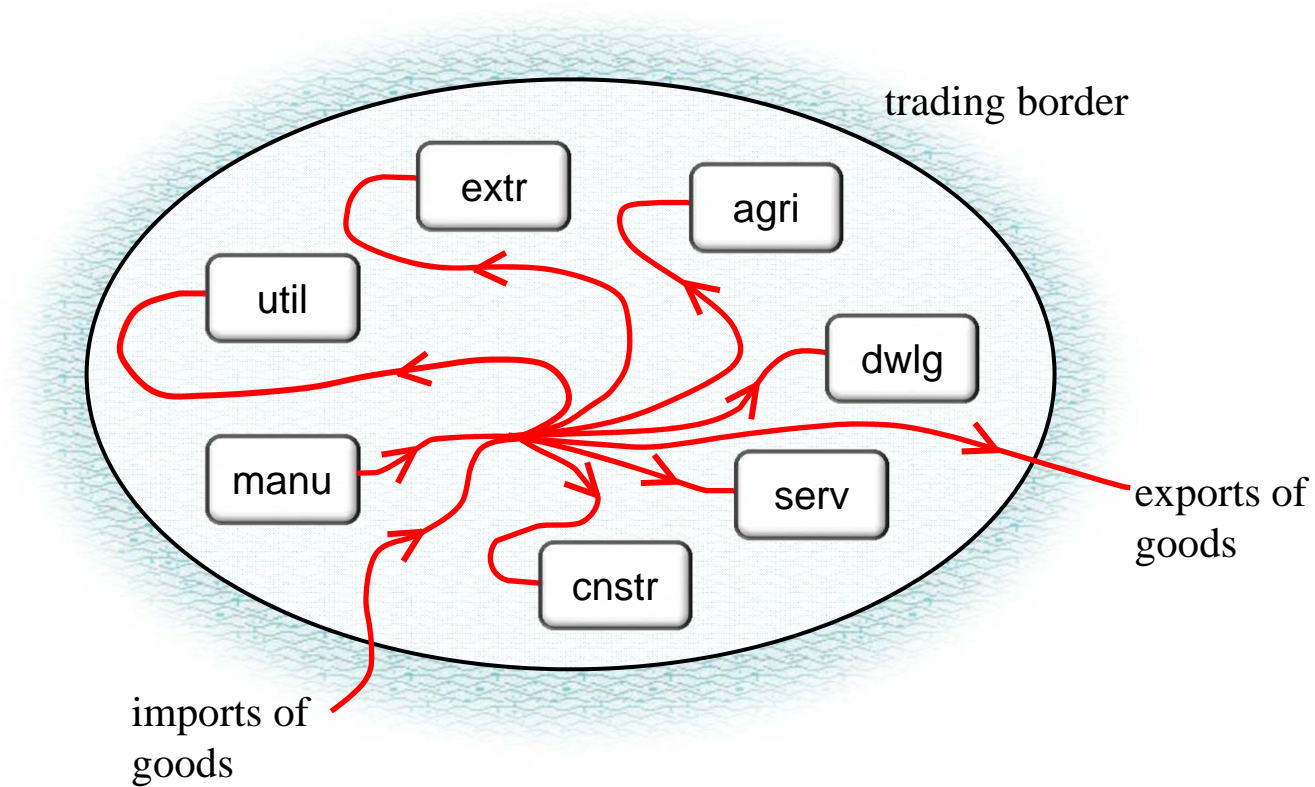
Divide up economy into industries & dwellings



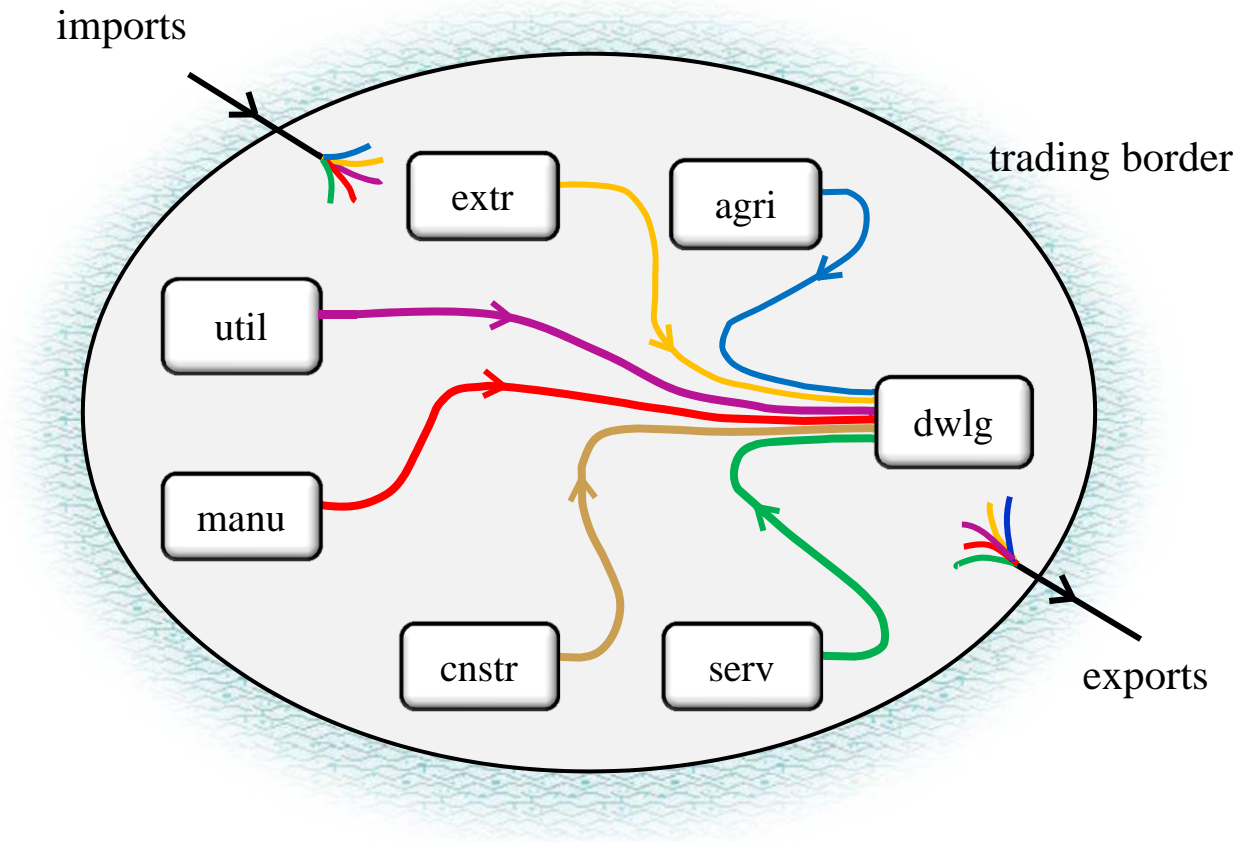
Volume flows, eg of goods



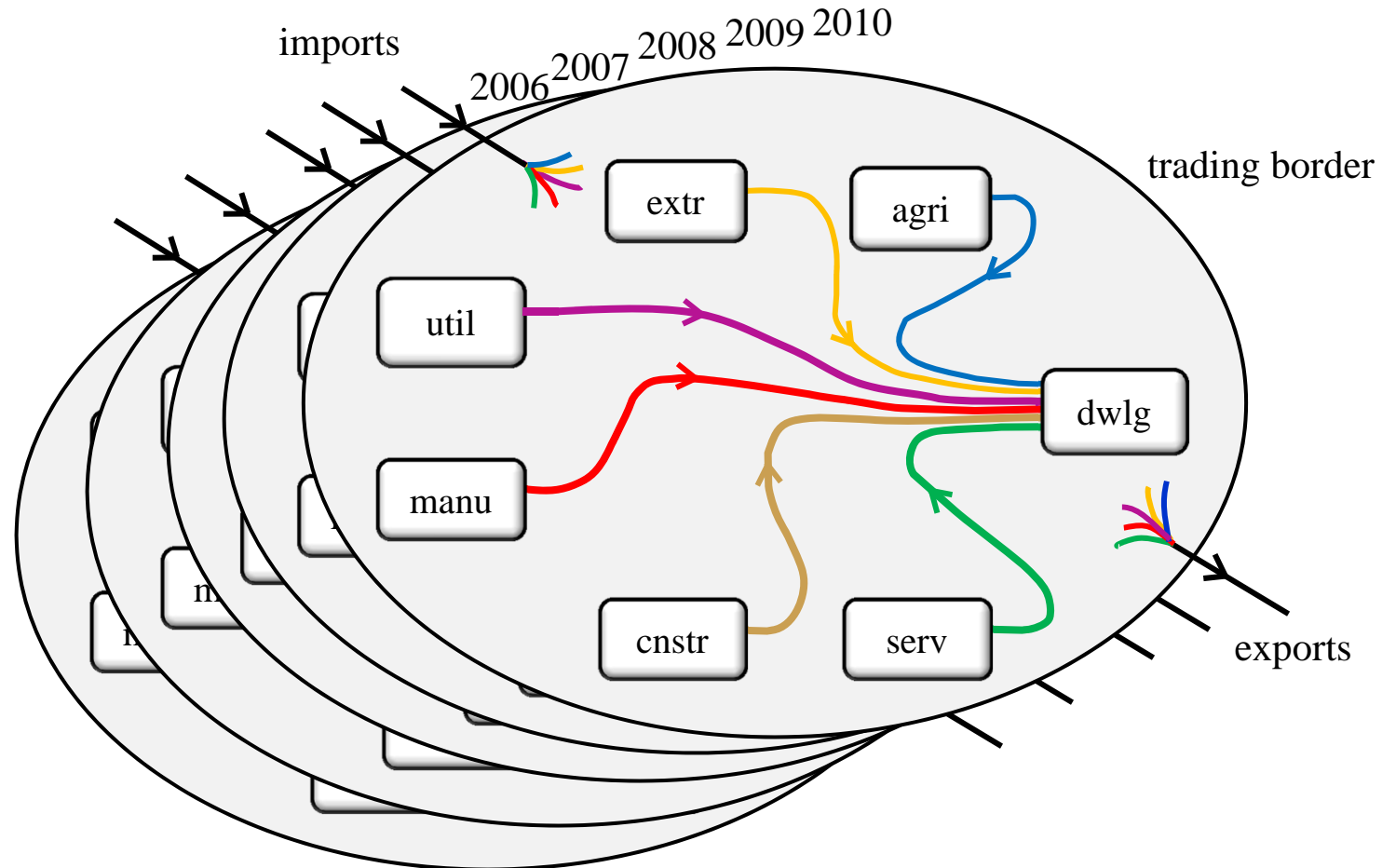
Volume flows to all users



Different flows leading to final demand



Historical data



Summary of the *4see* approach

1. At a national scale
2. Underpinned by data
3. Capture changes over time
4. Identify metrics amenable to a sort of conservation principle, cf conservation of mass, energy, momentum.
5. See where this journey takes us!

Start to quantify

Infrastructure of industries and dwellings

trading border

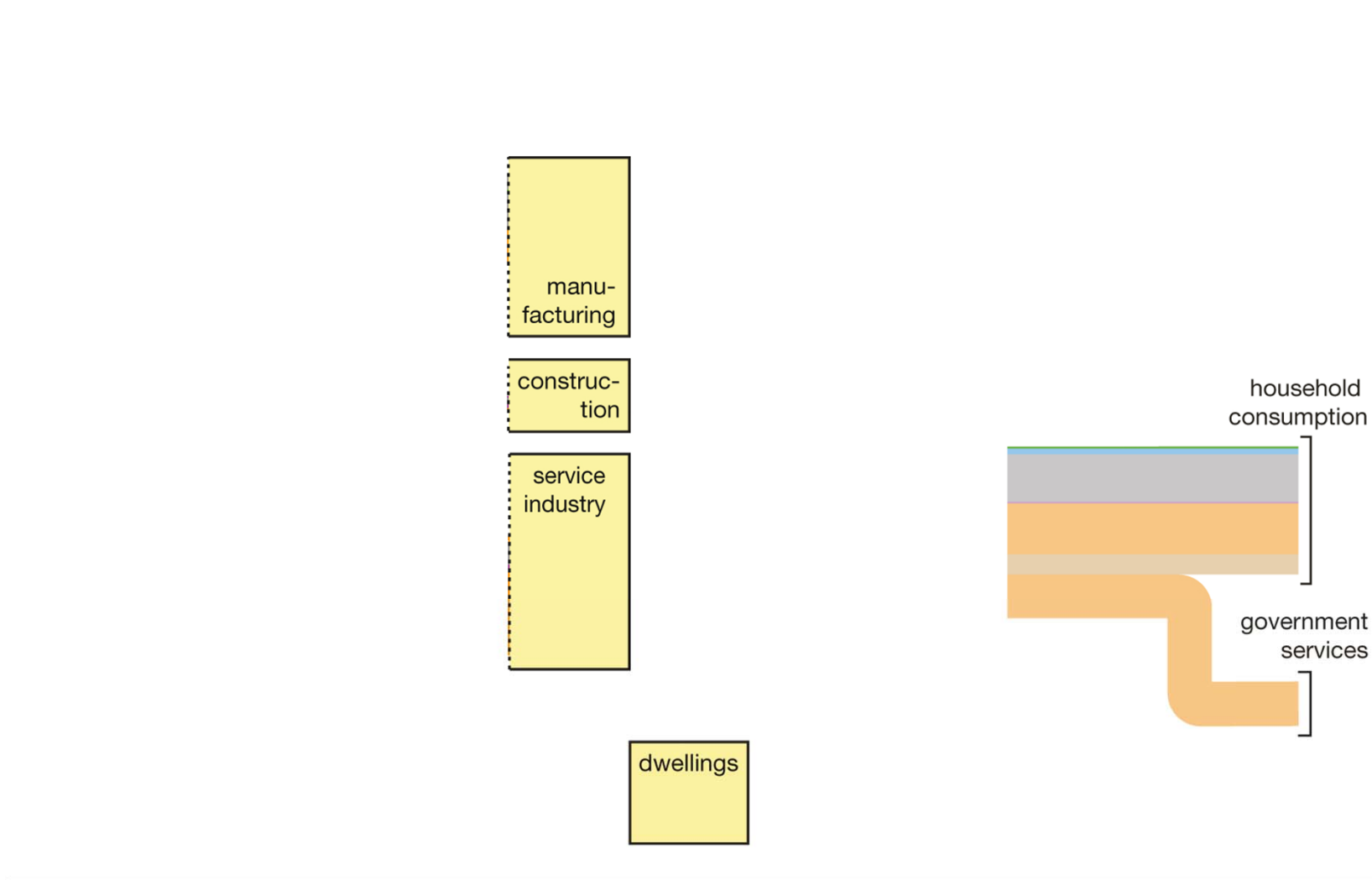
manu-
facturing

construc-
tion

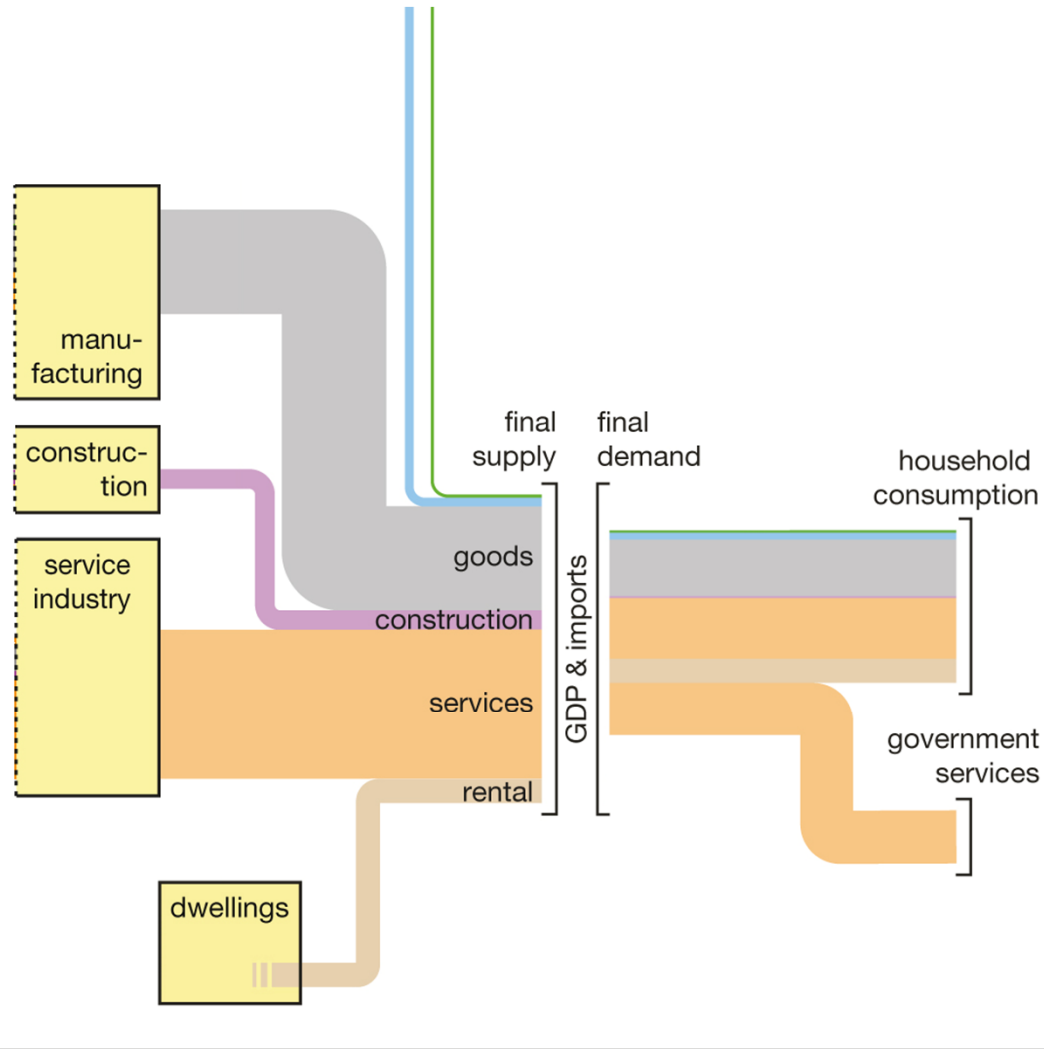
service
industry

dwellings

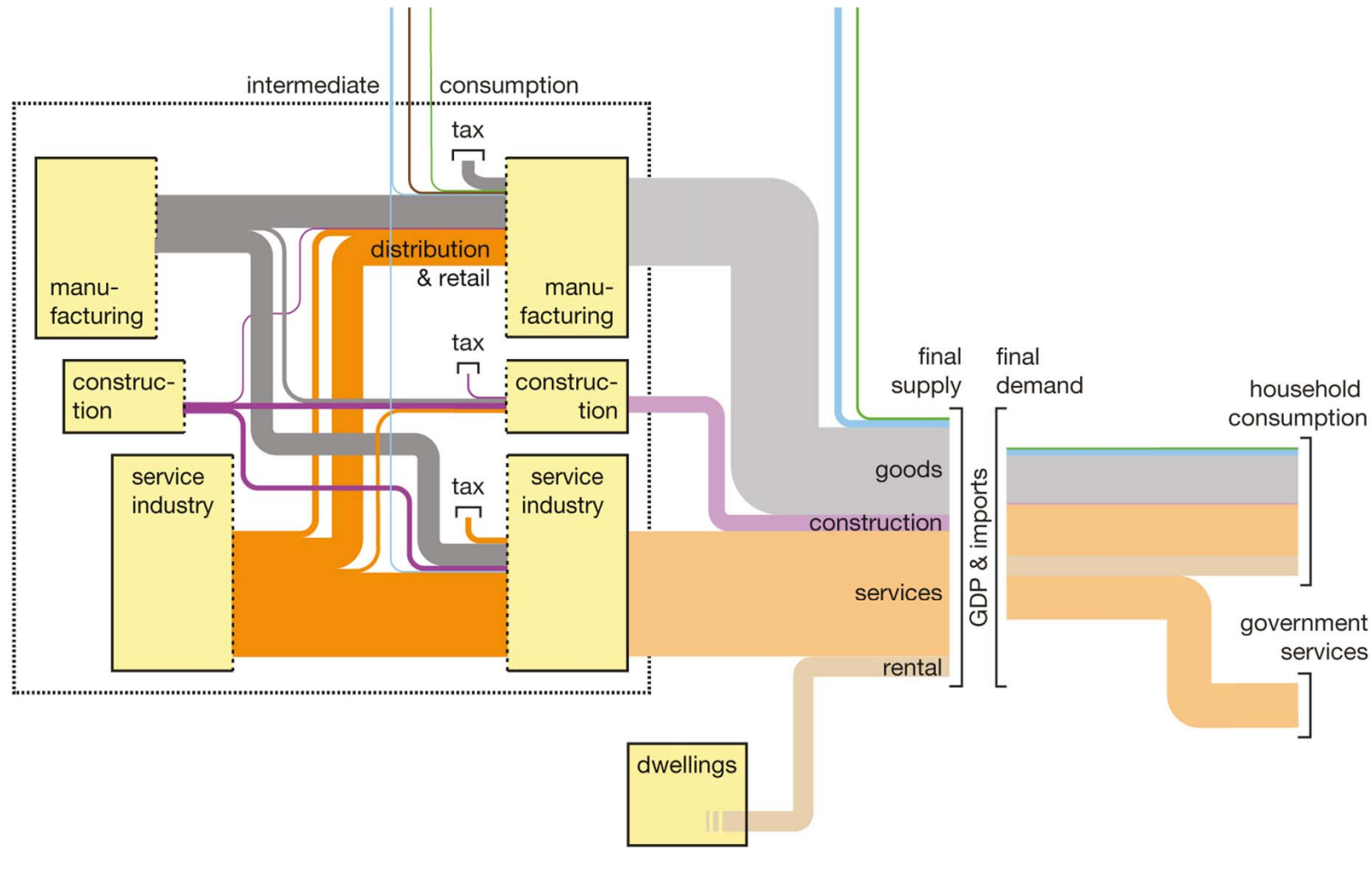
Final demand of household consumption



Final supply for final demand (GDP + imports)



Intermediate consumption between industries

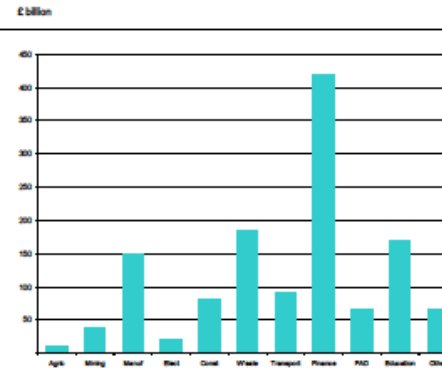


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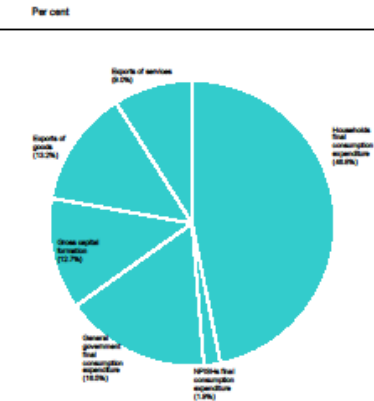
Supply Table

2008	SUPPLY OF PRODUCTS					
	Domestic output of products at basic prices	Imports		Taxes less subsidies on products	Total supply of products at purchasers' prices	
		Goods	Services			
PRODUCTS¹						
Agriculture, forestry & fishing [1-3]	24 036	8 338	504	4 984	553	38 395
Mining & quarrying [4-7]	50 846	35 422	720	2 084	534	89 606
Manufacturing [8-14]	431 461	297 162	17 180	244 853	85 038	1 076 724
Electricity, gas & water supply [15-17]	84 709	481	88	-	3 042	88 320
Construction [18]	217 882	-	1 189	-	12 469	231 540
Distribution & hotels [19-22]	376 188	-	15 582	-251 901	13 469	153 318
Transport & communication [23-26]	198 344	-	21 631	-	3 972	223 947
Finance & business services [100-114]	742 391	180	50 395	-	19 859	812 625
Public administration & defence [115]	139 955	-	46	-	-	139 901
Education, health & social work [116-118]	292 277	-	2 470	-	2 322	297 069
Other services [119-123]	111 083	3 819	5 708	-	7 909	128 219
Total	2 669 184	345 202	115 483	-	149 917	3 278 786
of which:						
Market output	2 202 785					
Output for own final use	115 543					
Other non-market output	349 876					

Gross value added at basic prices



Components of final demand



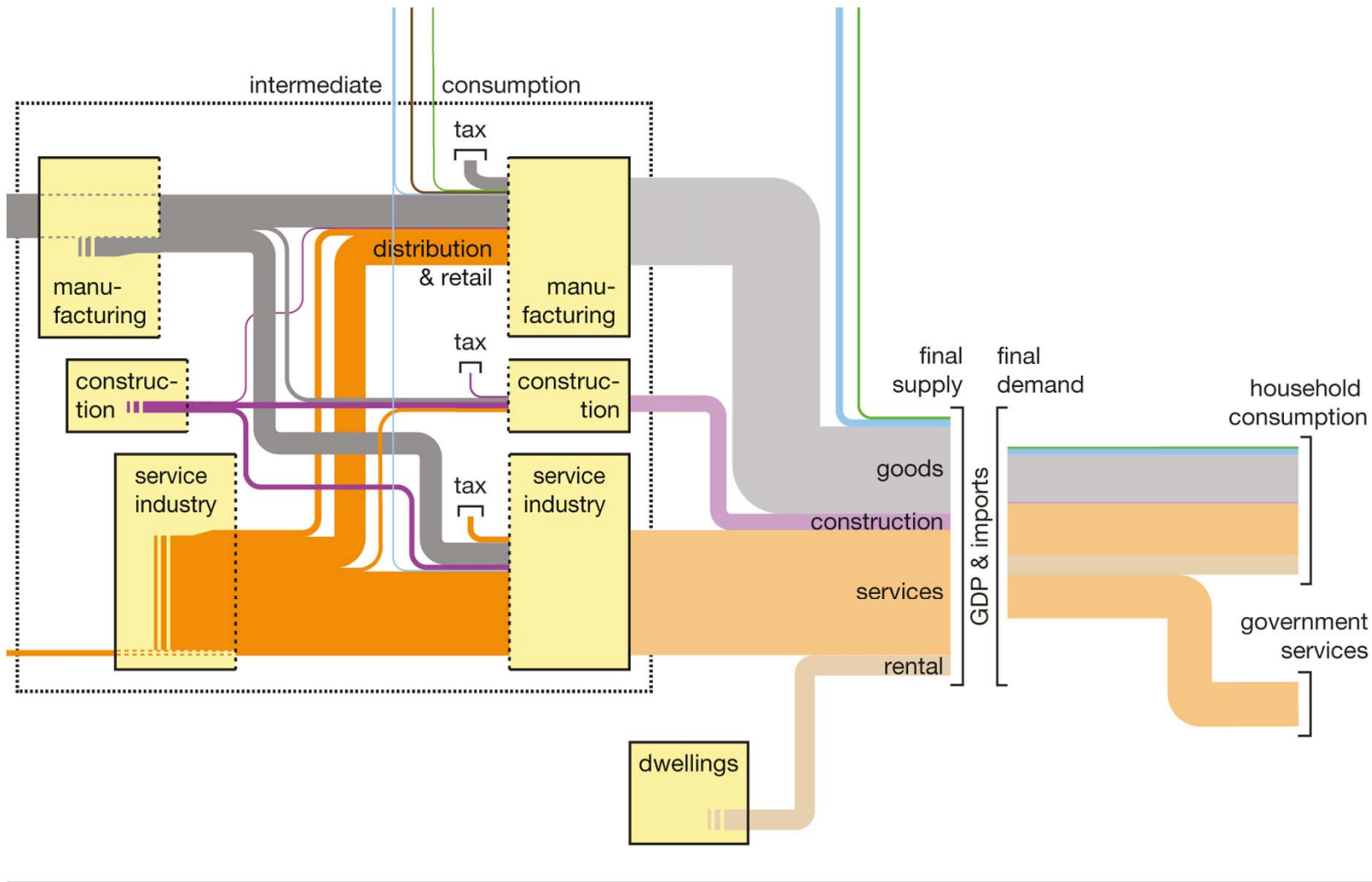
Use Table at Purchasers' prices

2008	INTERMEDIATE CONSUMPTION BY INDUSTRY GROUP ^{1,2}											FINAL CONSUMPTION EXPENDITURE				GROSS CAPITAL FORMATION		EXPORTS		TOTAL		
												Total intermediate consumption	Household	NPISHs	GGFC	GFCF	Changes in		Goods		Services	
	1	2	3	4	5	6	7	8	9	10	11						Valuables	Inventories				
PRODUCTS¹	PRODUCTS¹											PRODUCTS¹										
Agriculture, forestry & fishing [1-3]	2 940	2	12 343	10	300	2 000	78	18	-	314	50	18 053	16 946	-	-	1 159	-	-21	2 082	144	38 395	
Mining & quarrying [4-7]	8	5 135	27 063	28 873	2 919	291	93	17	-	9	59	54 426	279	-	-	569	-	616	23 239	500	89 606	
Manufacturing [8-14]	8 151	3 195	201 856	5 036	33 839	82 852	28 298	16 962	24 755	35 923	9 324	417 055	364 259	-	-	67 212	233	-1 893	223 028	6 763	1 076 724	
Electricity, gas & water supply [15-17]	827	1 028	12 467	28 717	388	2 833	1 159	2 147	1 832	2 828	811	82 095	35 899	-	-	-	-	41	112	83	88 320	
Construction [18]	380	767	1 062	720	63 570	1 628	3 332	15 293	5 313	1 254	755	93 274	7 786	-	-	128 681	-	531	-	1 268	231 540	
Distribution & hotels [19-22]	772	165	1 537	322	2 040	8 050	3 831	7 284	2 029	2 937	838	39 805	112 601	-	-	-	381	-	-5	-	10 537	153 318
Transport & communication [23-26]	554	1 425	15 857	475	1 616	35 310	42 631	29 243	5 731	6 692	3 109	142 443	95 913	-	-	1 286	-	53	-	24 252	223 947	
Finance & business services [100-114]	2 827	3 995	38 205	4 796	27 691	66 029	32 720	183 292	25 082	27 671	21 538	443 839	211 137	1 425	-	35 600	-	882	132	119 610	812 625	
Public administration & defence [115]	12	31	846	56	487	283	2 209	8 536	318	105	91	12 778	4 057	-	-	118 263	2 741	-	-	-	1 162	139 901
Education, health & social work [116-118]	217	59	1 417	237	222	1 186	1 380	6 448	5 388	39 424	1 154	57 082	30 301	25 916	181 350	-	-	56	-	-	2 434	297 069
Other services [119-123]	328	196	3 749	221	205	2 230	2 112	5 362	3 788	4 388	19 106	41 631	52 604	8 591	14 401	3 064	-	36	3 523	4 049	128 219	
Total consumption	16 716	15 920	316 094	67 489	133 247	172 512	113 821	284 832	73 885	122 401	85 844	1 372 521	892 194	35 832	314 044	240 361	614	295	252 086	170 819	3 278 786	
Taxes less subsidies on production	-2 854	688	2 469	1 288	945	9 288	873	2 544	-	402	1 041	16 754										
Compensation of employees	4 466	3 914	107 301	6 240	41 964	119 477	82 387	179 913	55 530	145 204	42 155	789 191										
Gross operating surplus	8 091	33 116	39 696	13 825	37 817	54 821	28 087	237 423	9 581	24 662	22 387	509 688										
Gross value added at basic prices	9 715	37 718	150 296	21 342	80 756	183 586	91 347	419 980	65 090	170 259	85 563	1 295 663										
Output at basic prices	25 431	53 636	486 362	88 811	214 003	356 086	205 158	704 612	138 955	292 659	121 407	2 669 184										

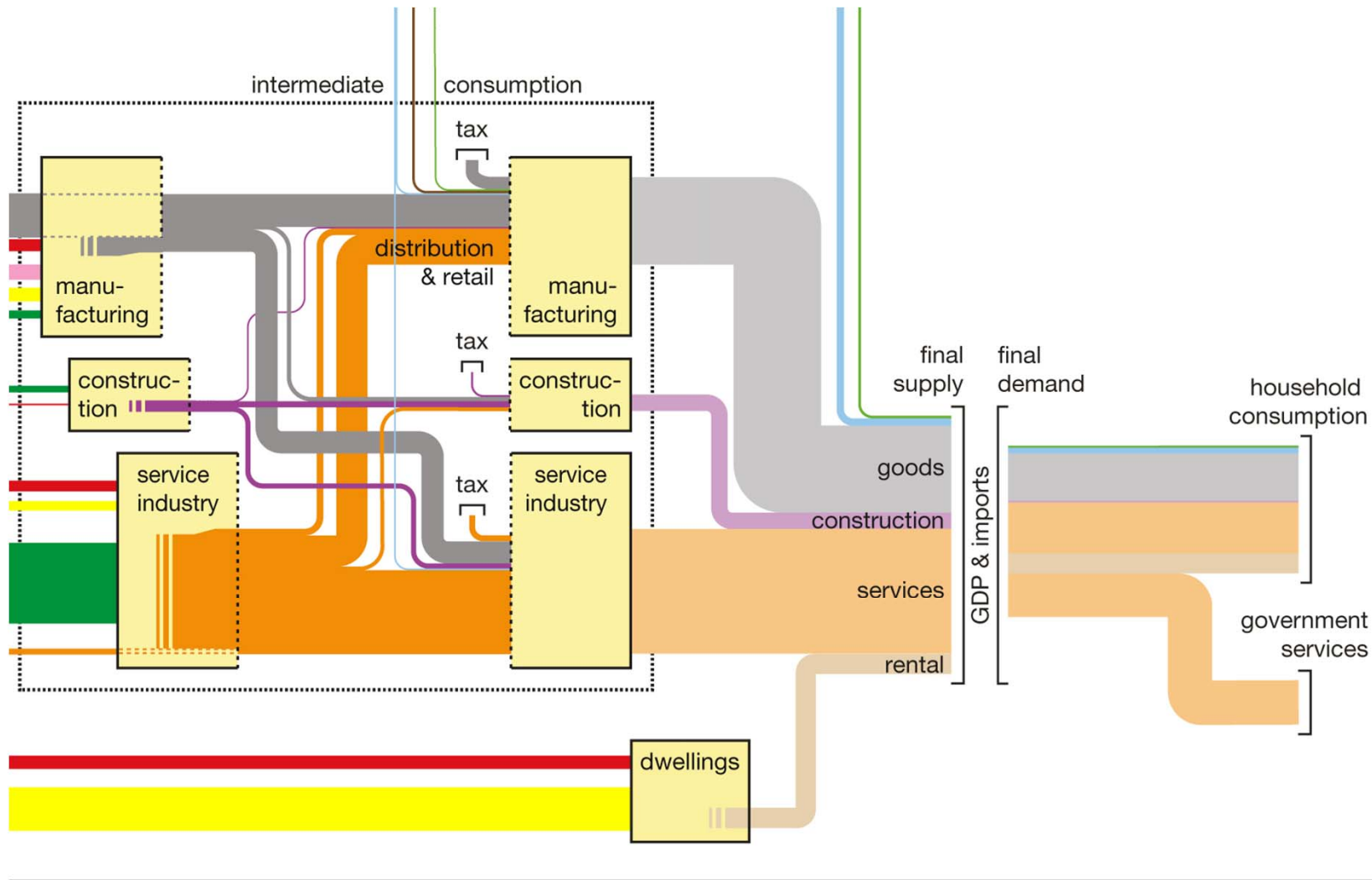
Notes for information
 (1) Some of the industry/product group headings have been truncated.
 (2) Purchases of products by industry and by final consumption categories are valued at purchasers' prices.
 NPISHs represents Non-Profit Institutions Serving Households.
 GGFC represents General Government Final Consumption.
 GFCF represents Gross Fixed Capital Formation.
 Gross value added at basic prices plus taxes less subsidies on products gives GDP at market prices.
 Gross operating surplus includes gross mixed income.
 Changes in inventories includes materials and fuels, work-in-progress and finished goods.
 Valuables include both 'transfer costs' and 'acquisitions less disposals'.

Supply and Use Tables for deriving GDP

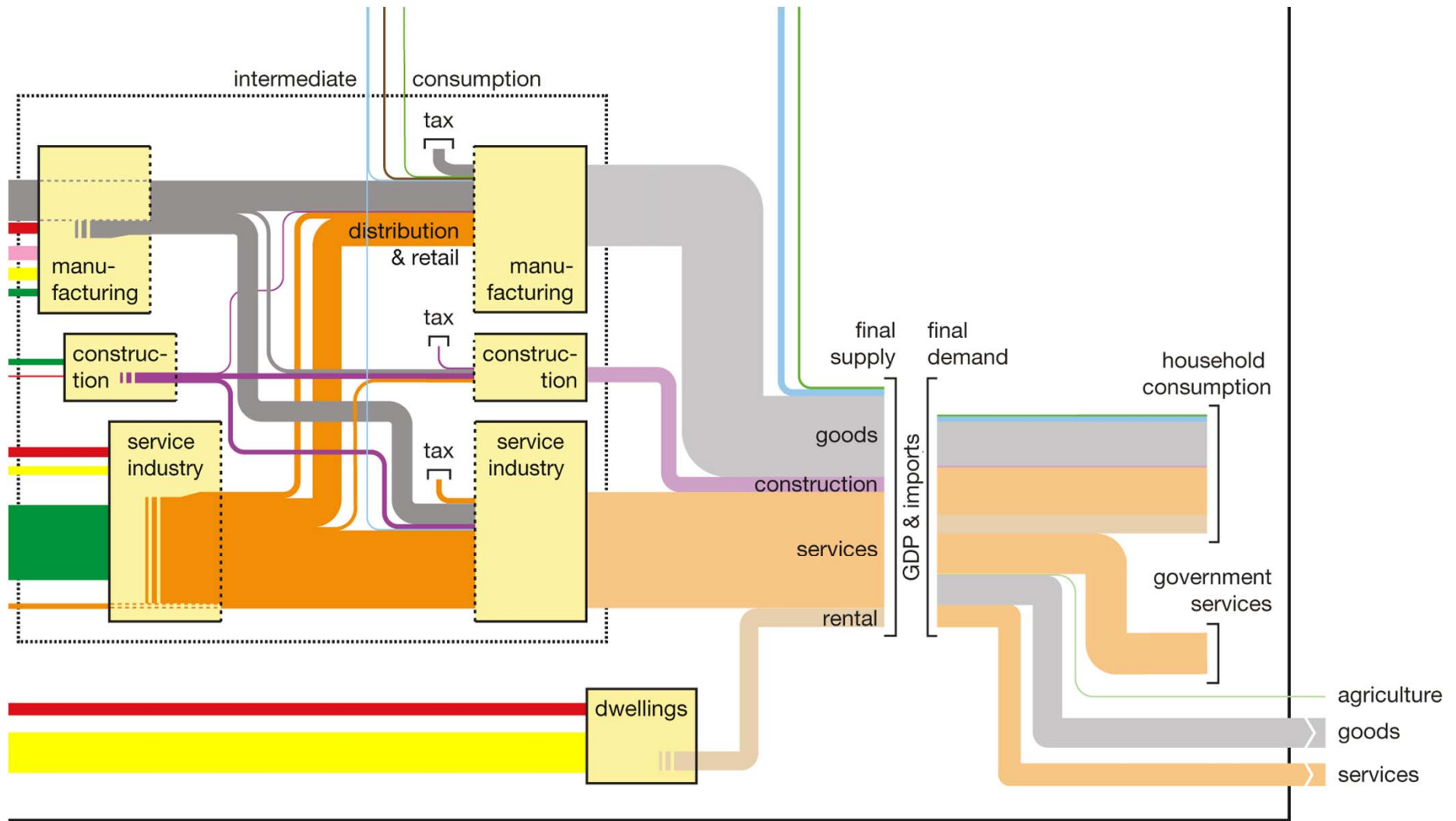
GVA (gross valued added) & imports



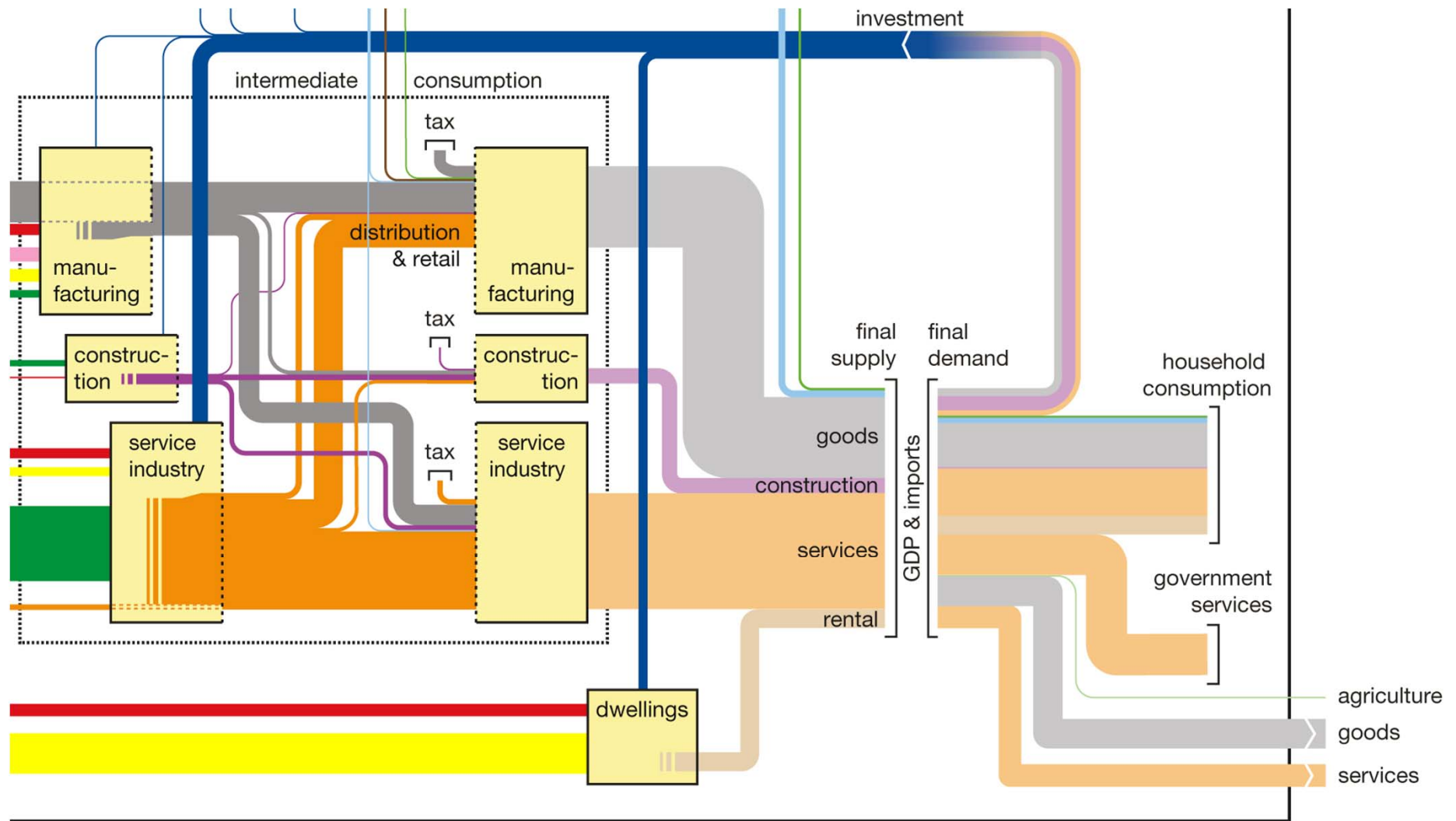
Other inputs: fuel, electricity, jobs



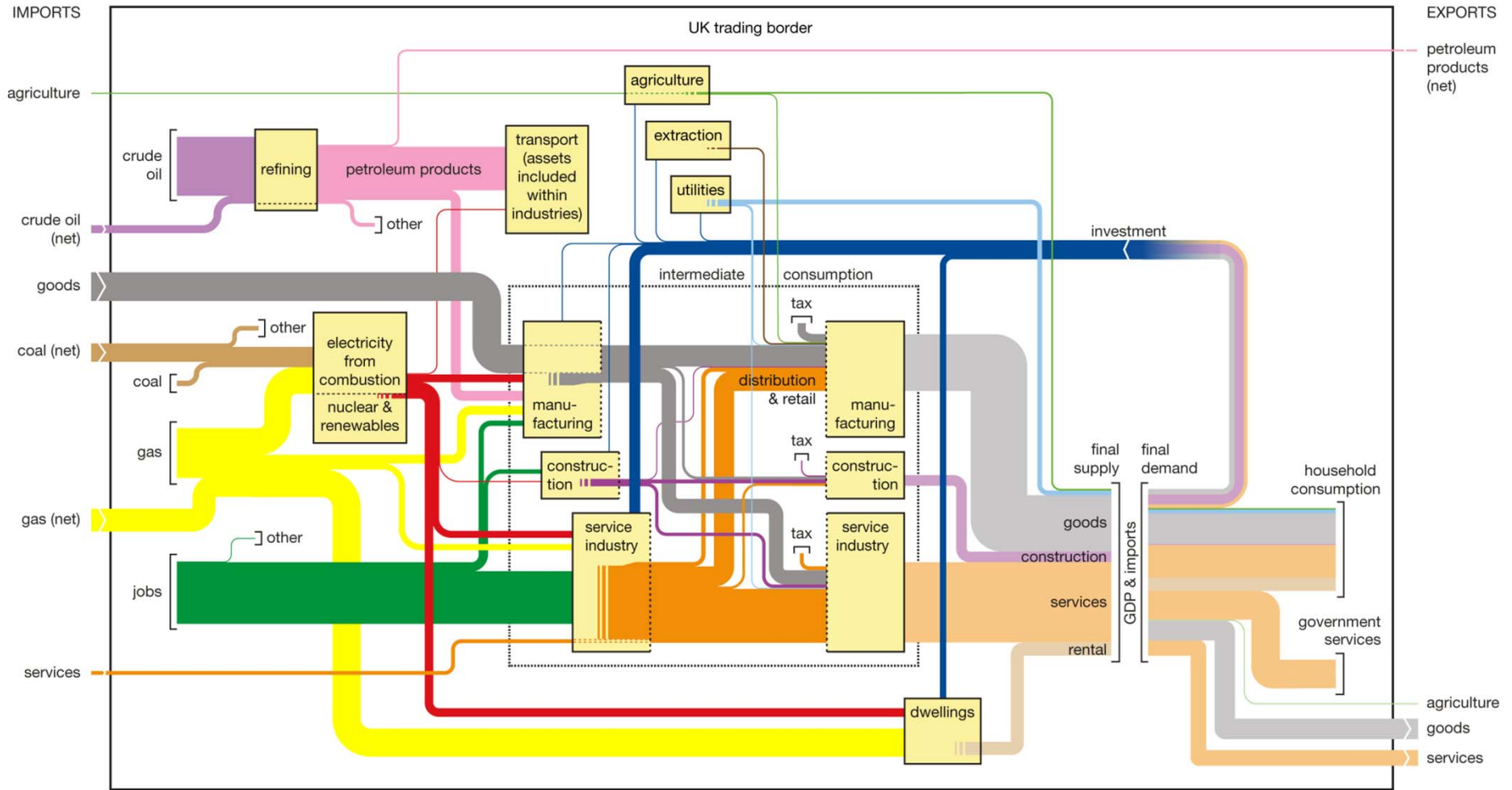
Exports



Investment (GFCF, gross fixed capital formation)



Full economy of GB (2010)



KEY

energy (500 PJ/y)

- █ crude oil
- █ petroleum products
- █ coal
- █ natural gas

- █ electricity (200 TWh/y)
- █ jobs (10 million)

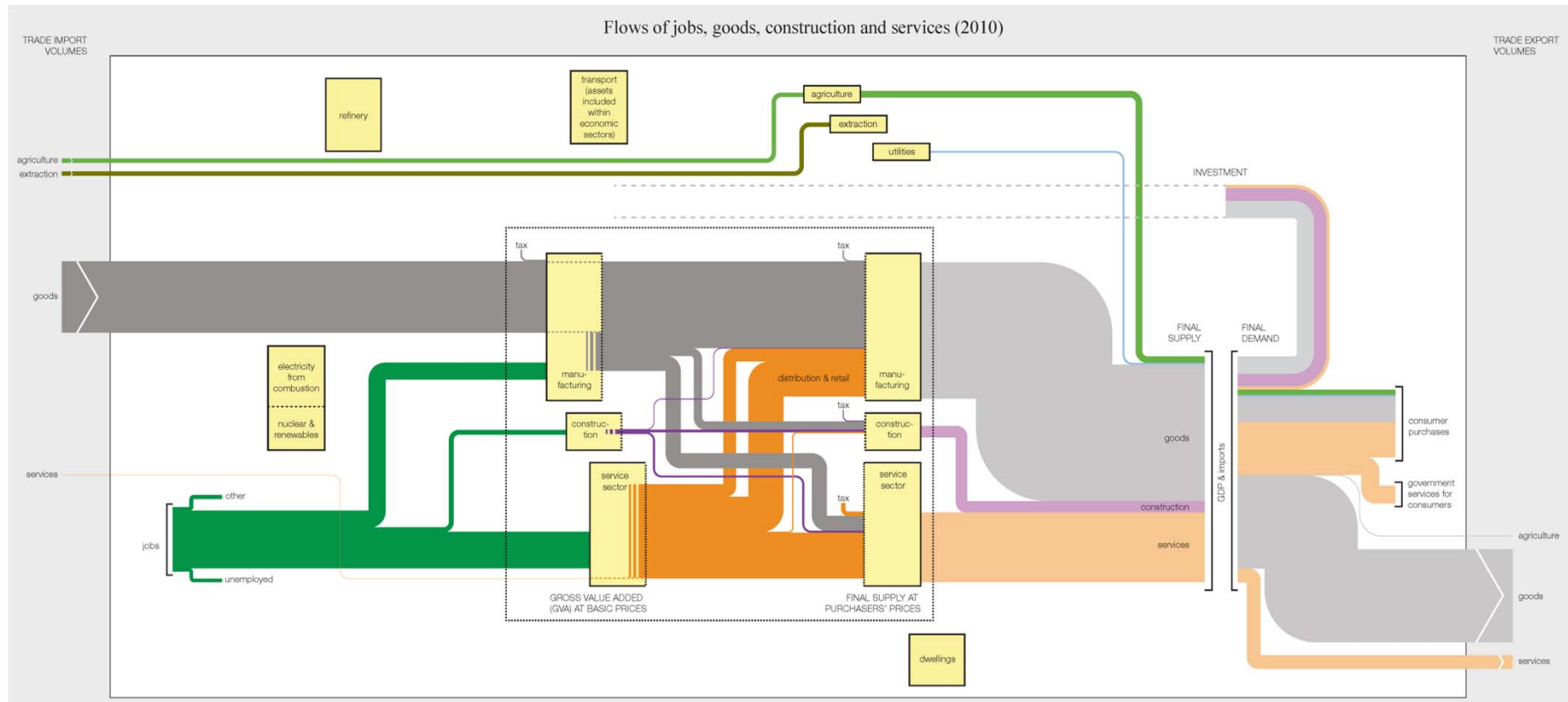
volume flows at basic prices (100 £b[1990]/y)

- █ goods
- █ construction
- █ services

volume flows at purchasers' prices (100 £b[1990]/y)

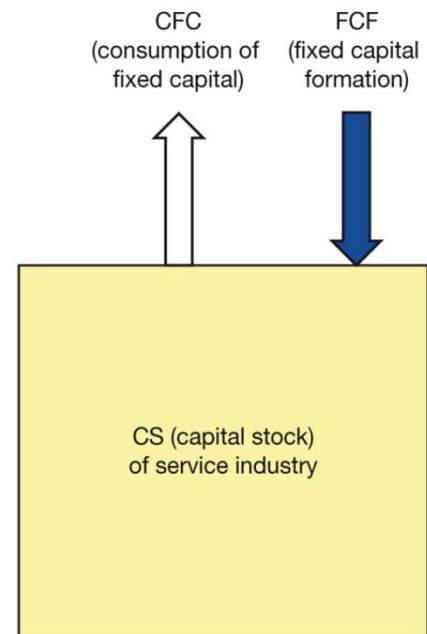
- █ goods
- █ construction
- █ services
- █ rental (actual + imputed)
- █ agriculture
- █ utilities
- █ investment

Initial work on economy of TW (2010)

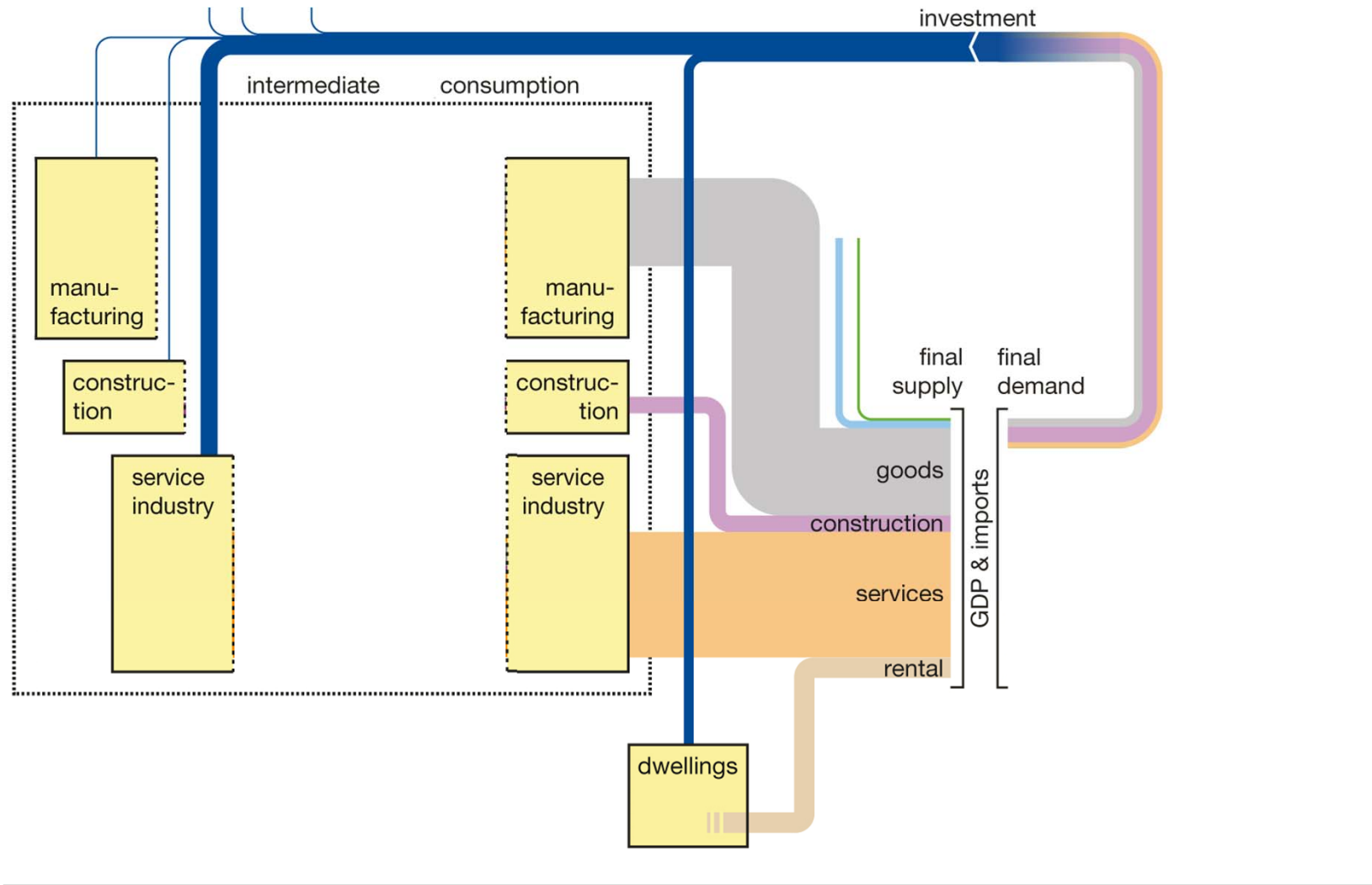


Stocks-and-flows and process flows

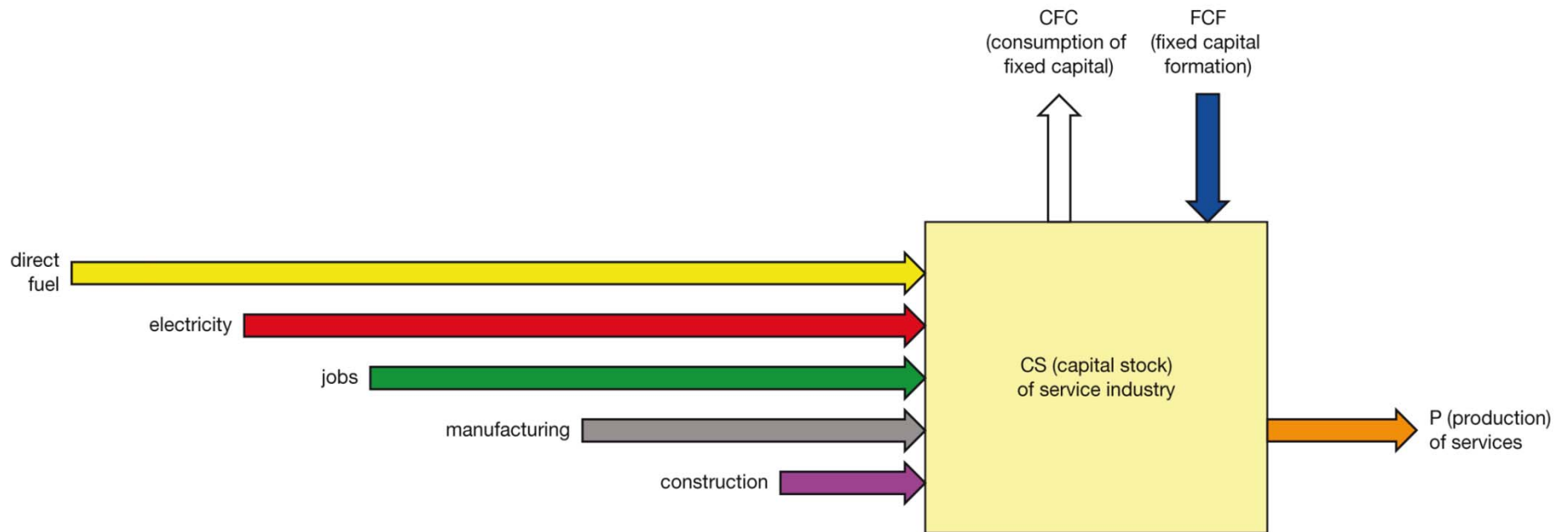
Stocks-and-flows



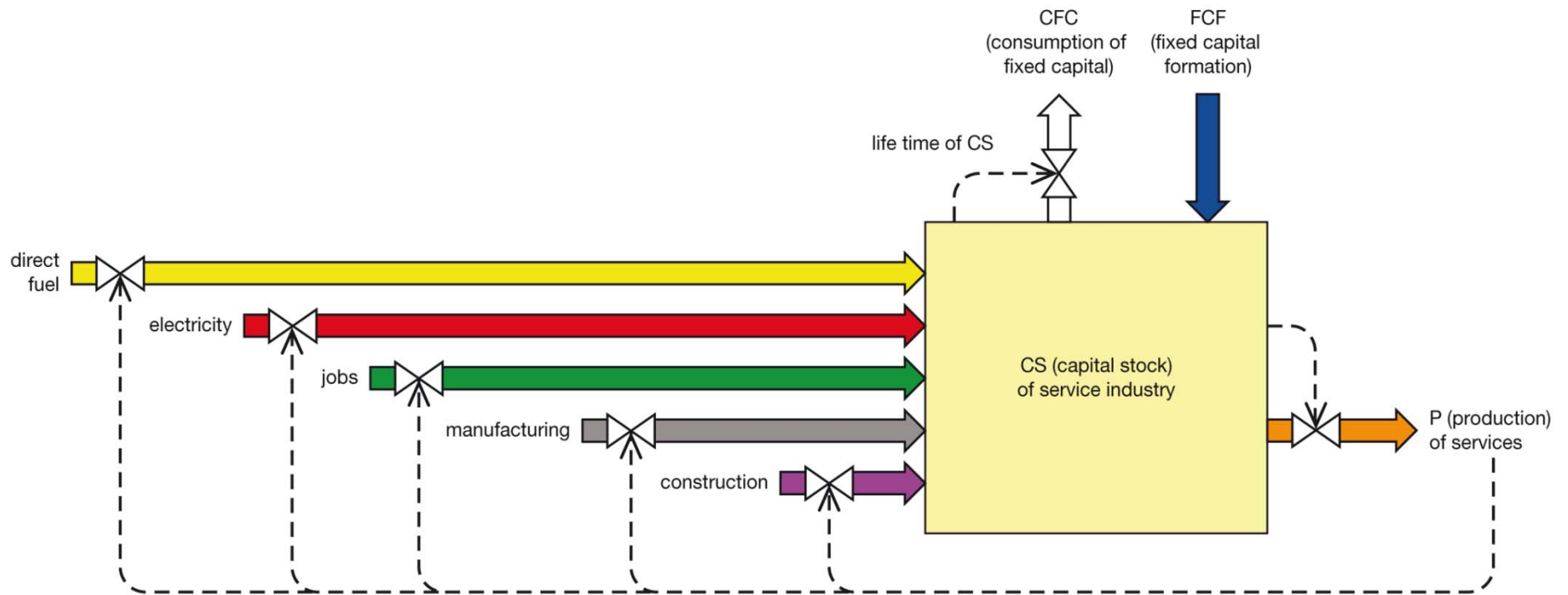
Investment



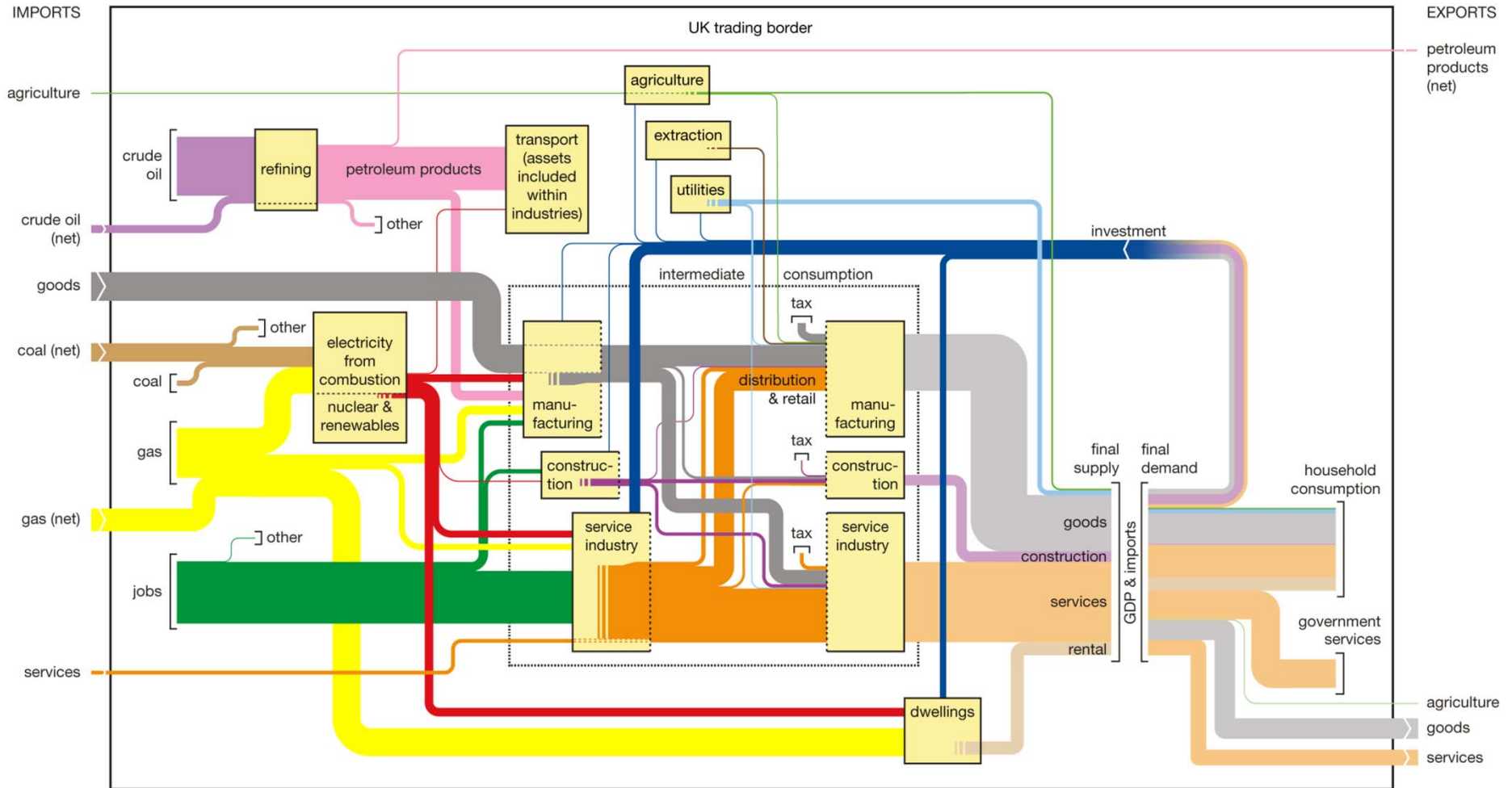
Process flows



Dependencies

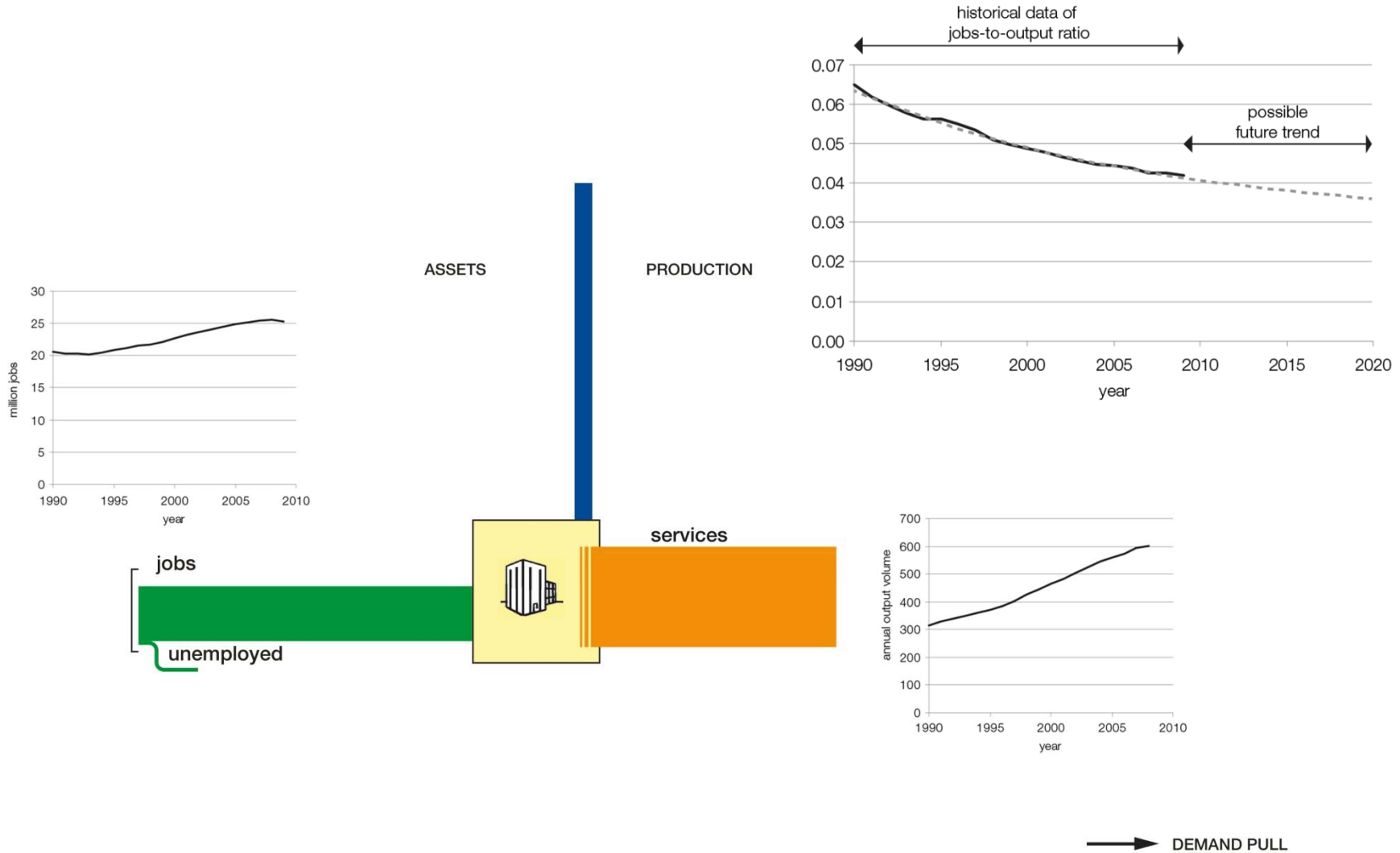


Full economy of GB (2010)



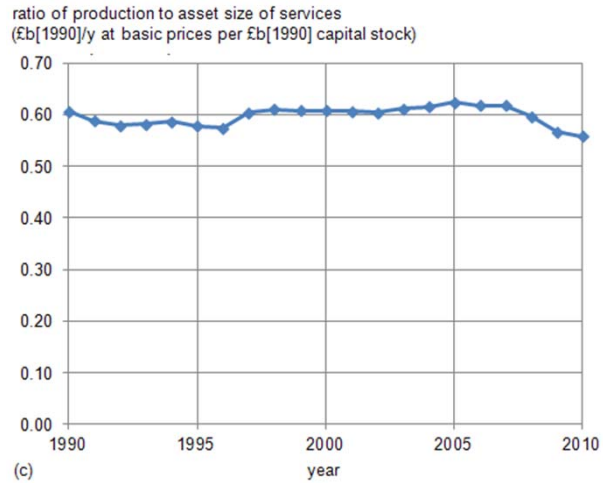
KEY	energy (500 PJ/y)	volume flows at basic prices (100 £b[1990]/y)	volume flows at purchasers' prices (100 £b[1990]/y)
	crude oil	goods	goods
	petroleum products	construction	construction
	coal	services	services
	natural gas		rental (actual + imputed)
	electricity (200 TWh/y)		agriculture
	jobs (10 million)		utilities
			investment

Service industry



Future scenarios

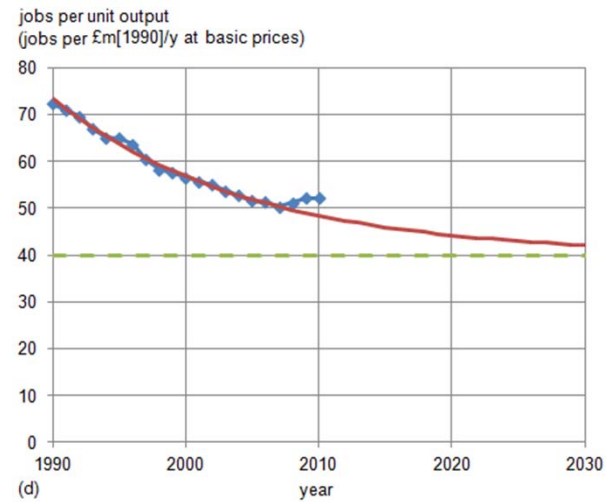
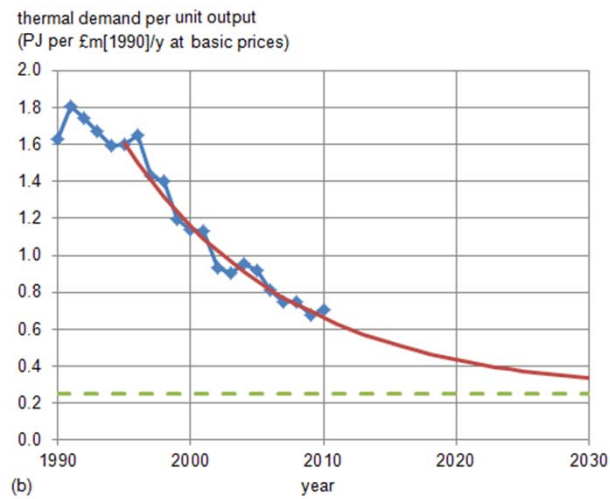
BAU by trending relationship ratios



output per unit capital

thermal energy per unit output

jobs per unit capital



Generation:

- Wind turbines
- Biomass electricity
- Bioenergy boilers
- Solar thermal hot water
- PV (photovoltaics)
- CCS (carbon capture and sequestration)
- CSP (concentrator solar power) electricity transmitted from North Africa

Consumption:

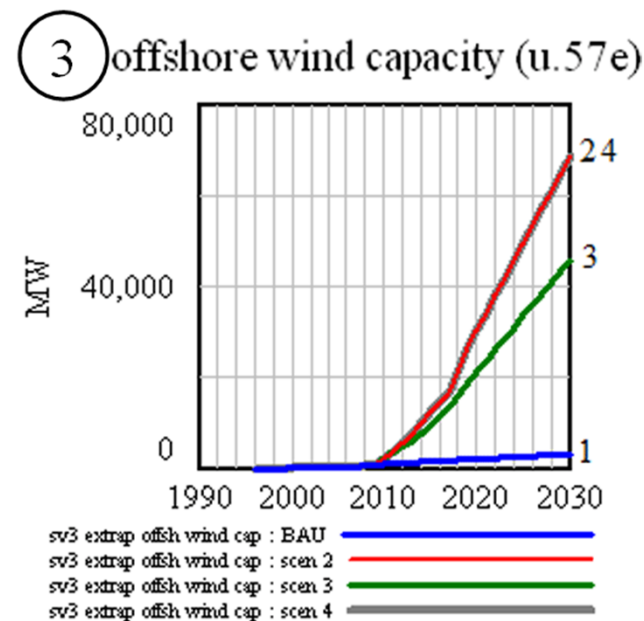
- Efficiency in workspace, warehouse and retail
- Aviation efficiencies
- *Passiv haus* new housing
- Double glazing
- Loft insulation
- Cavity wall insulation
- Solid wall insulation
- Heat pumps
- LED lighting

Transportation:

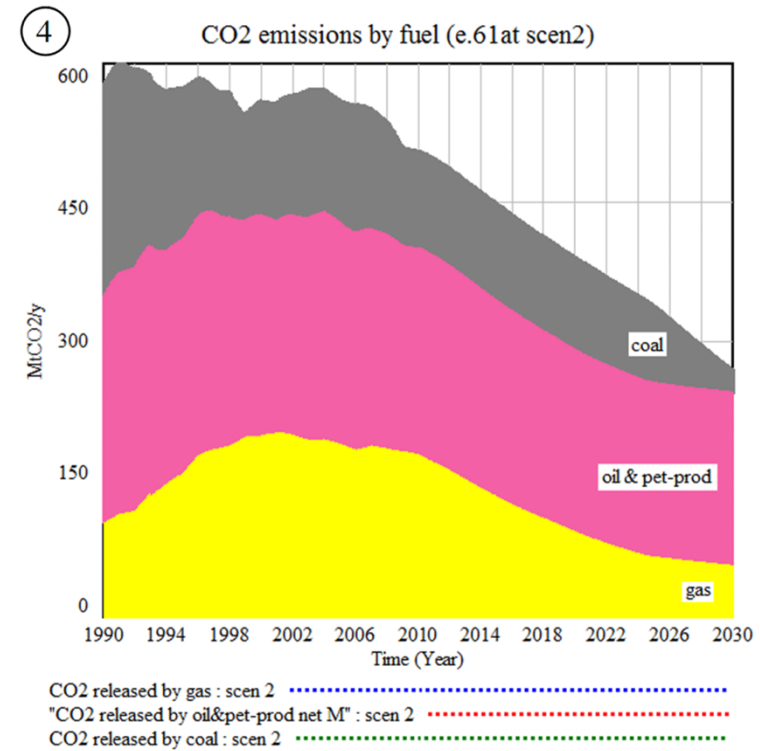
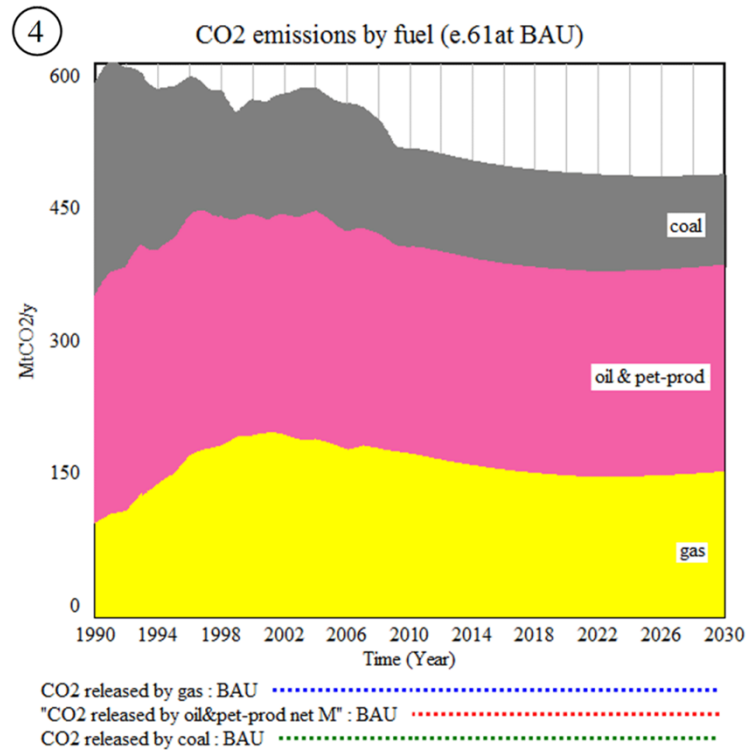
- Biomass electricity
- Bioenergy boilers
- Solar thermal hot water
- PV (photovoltaics)
- CCS (carbon capture and sequestration)
- CSP (concentrator solar power) electricity transmitted from North Africa

Requirements for each investment measure

1. Scale of feasible implementation,
2. Additional cost for implementation,
3. Their generation of energy or reduction of energy demand.



CO₂ emissions of BAU compared to all measures



Closing comments

Components of *4see*

1. Start with the infrastructure (**fixed capital**)
2. *Supply and Use Tables* (System of National Accounts)
3. Follow volumes **forwards** (rather than money backwards)
4. Infrastructure (fixed capital) **gives rise** to production
5. Production requires **inputs**, which are complementary
6. Coefficients of input-to-production **evolve** over time
7. Final consumption provides (exogenous) **demand-pull**
8. Shift household consumption to **investment** (GFCF)
9. Quantify **measures** examined by others

Observations from applying the *4see* model

- The *4see* model can calculate marginal costs to the economy
- A shift from final consumption (of GDP) to investment might increase unemployment
- *4see* scenarios are a starting point for examining system interactions and sensitivities of investment measures

Observations

- Collecting data is non-trivial but feasible.
- Many relationships are smooth
- Few surprises to individual specialists...
- ...but breaks down barriers between specialisms

To do:

- *4see* models of more countries in addition to:
 - GB (Great Britain)
 - TW (Taiwan)
 - AU (Australia)
- Investigate historical trends of relationships
- Sensitivity analysis of business-as-usual scenarios
- Research measures for low-carbon transition
- Develop future scenarios

Thank you