Renewables and energy efficiency – low emission systems outside and inside cities

Mark Barrett
mark.barrett@ucl.ac.uk

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[Note: presentation has animations which run if presentation is run]

OVERVIEW

To maintain a habitable environment:

- World ~70% reduction in GHG on 2010 base
- For equity, rich countries ~95% GHG reduction

=> In rich countries like UK
~ Zero GHG stationary demand & supply sectors
~Zero GHG shipping?
Then we can fly on holiday once every 5 years

Demand side

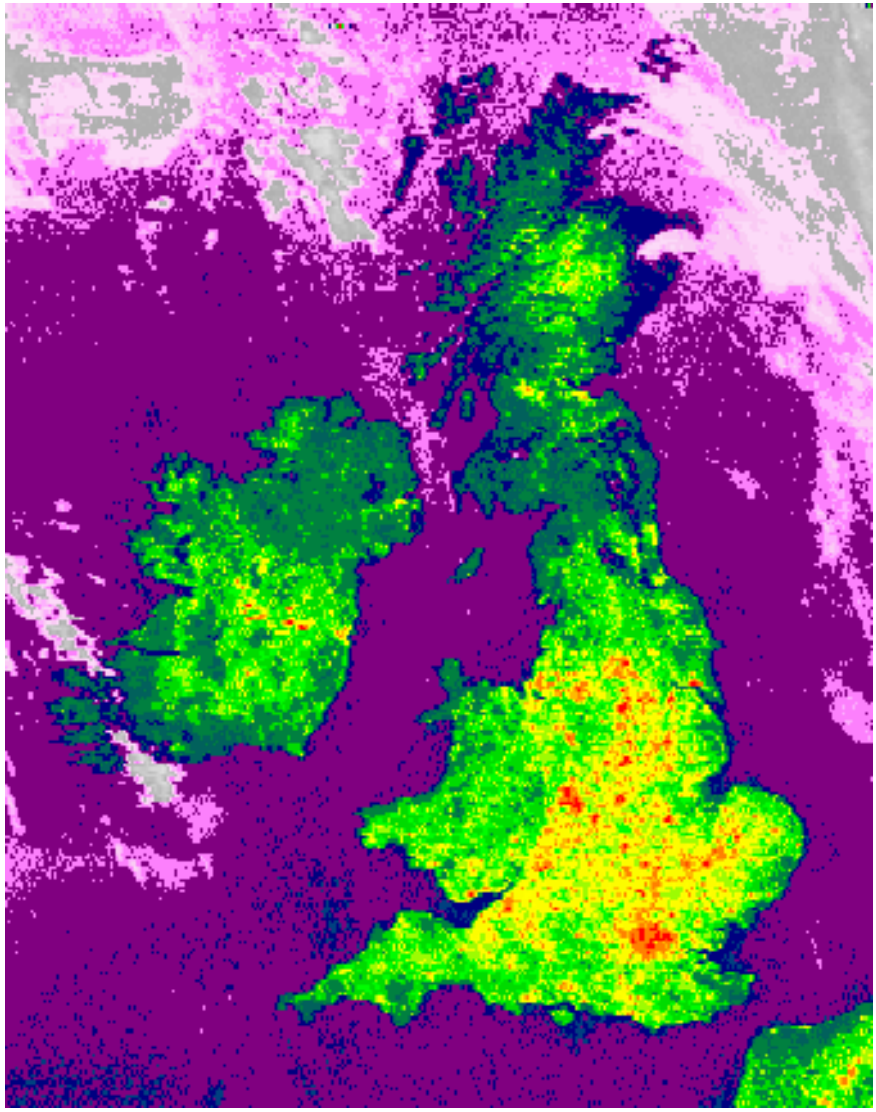
- Behavioural
- Technical

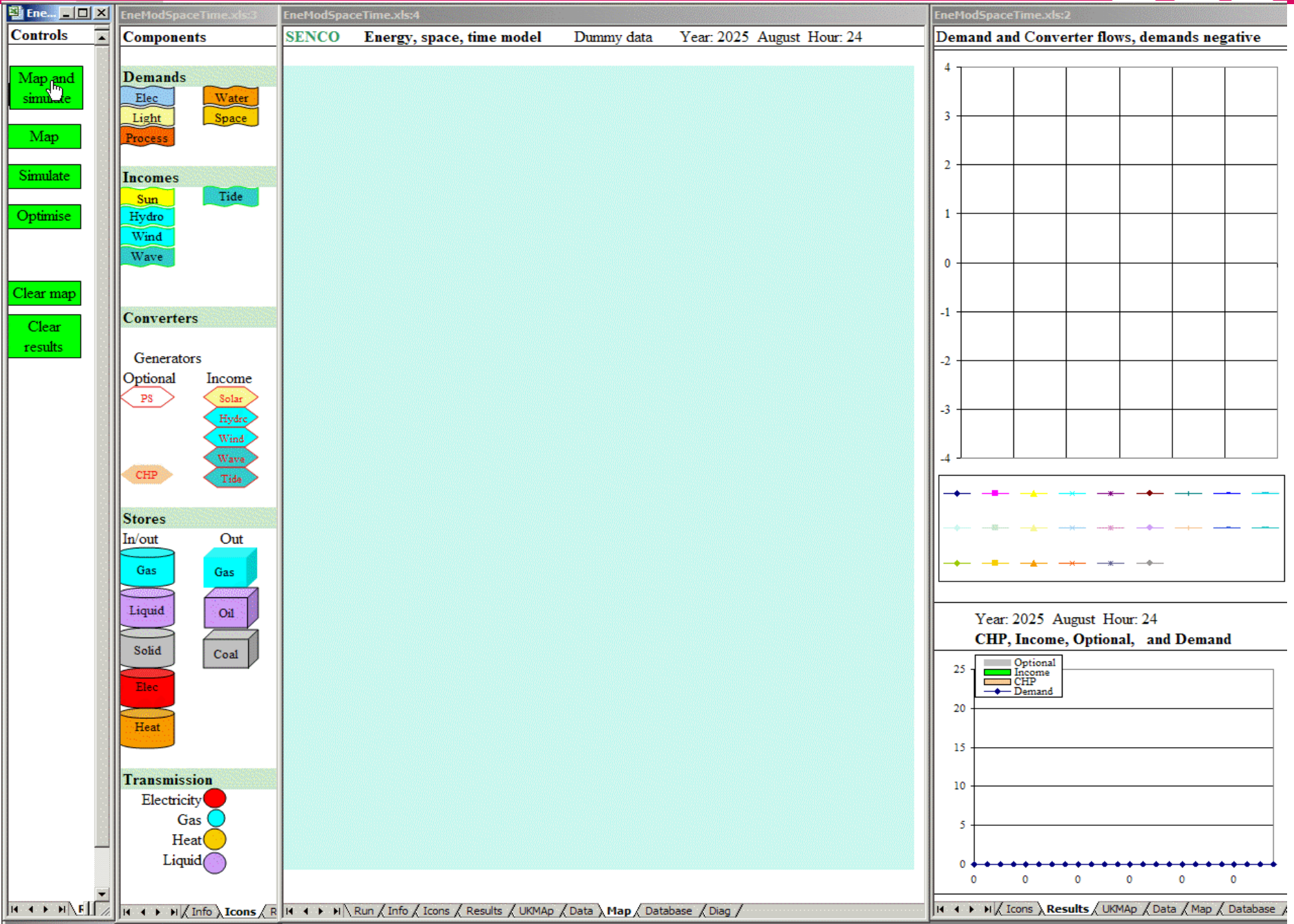
Supply side

- Nuclear – severe problems
- Carbon sequestration – severe problems

So

- **Renewables – abundant but variable temporally and spatially**




Controls
Map and simulate
Map
Simulate
Optimise
Clear map
Clear results
Components
Demands
Elec
Light
Process
Water
Space
Incomes
Sun
Hydro
Wind
Wave
Tide
Converters
Generators
Optional
Income
PS
CHP
Solar
Hydro
Wind
Wave
Tida
Stores
In/out
Out
Gas
Liquid
Solid
Elec
Heat
Gas
Oil
Coal
Transmission
Electricity
Gas
Heat
Liquid
SENCO Energy, space, time model Dummy data Year: 2025 August Hour: 24
Demand and Converter flows, demands negative
4
3
2
1
0
-1
-2
-3
-4
Year: 2025 August Hour: 24
CHP, Income, Optional, and Demand
Optional
Income
CHP
Demand
25
20
15
10
5
0
Info
Icons
Run
Info
Icons
Results
UKMAp
Data
Map
Database
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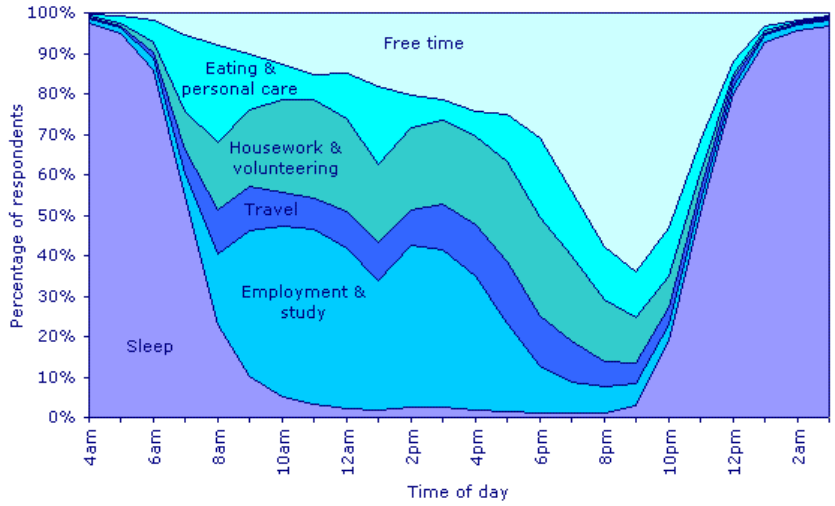
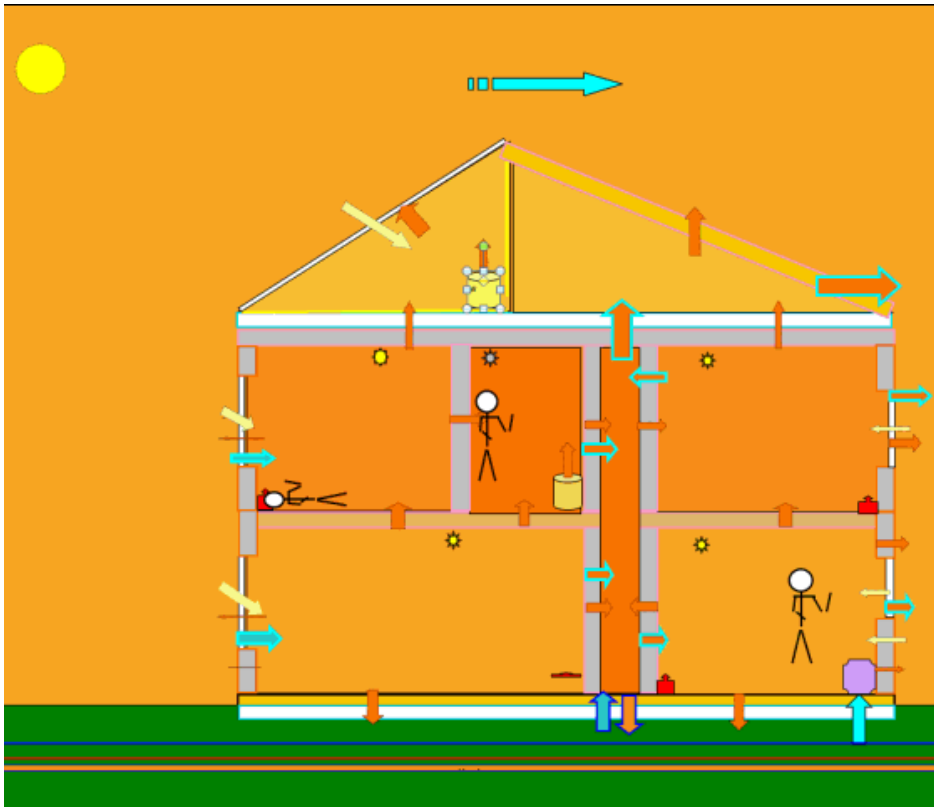
Icons
Results
UKMAp
Data
Map
Database

DynEMo Temporal drivers

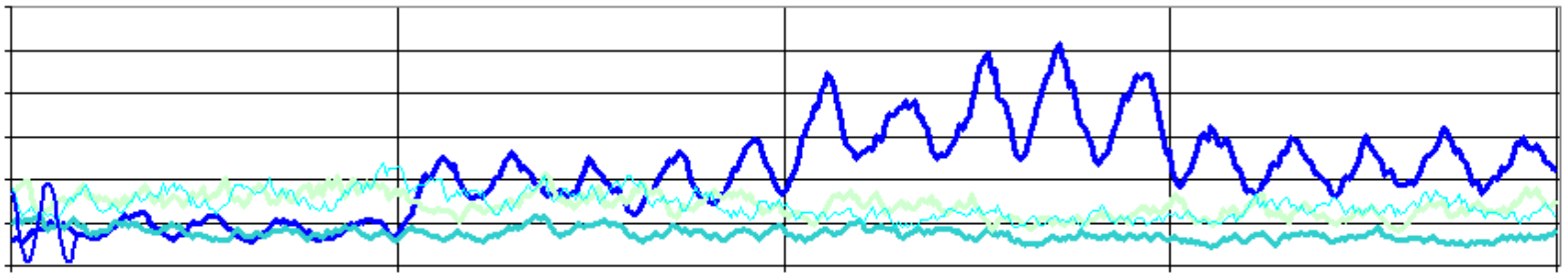
Human use of time – UK

Quite invariable –
a diurnal mammal!

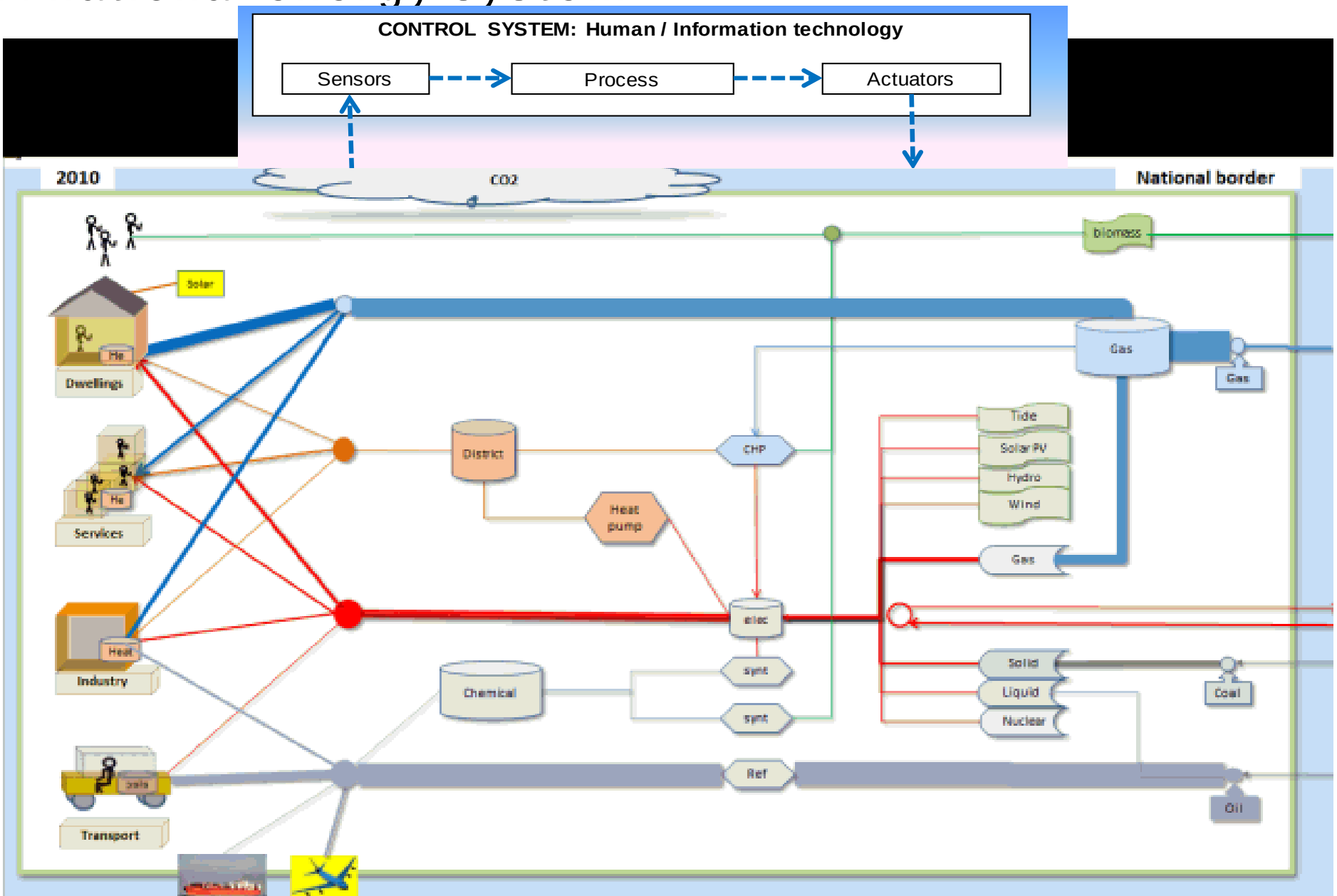




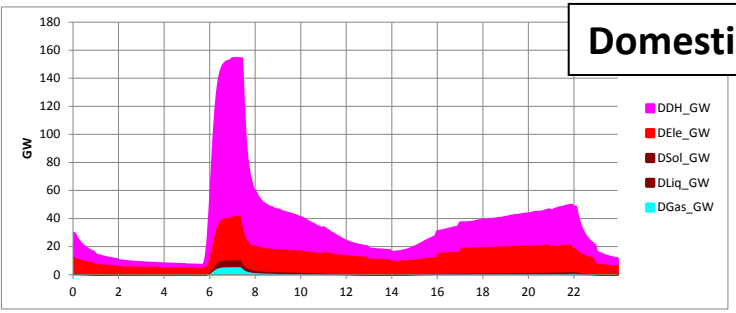
Weather and Renewables

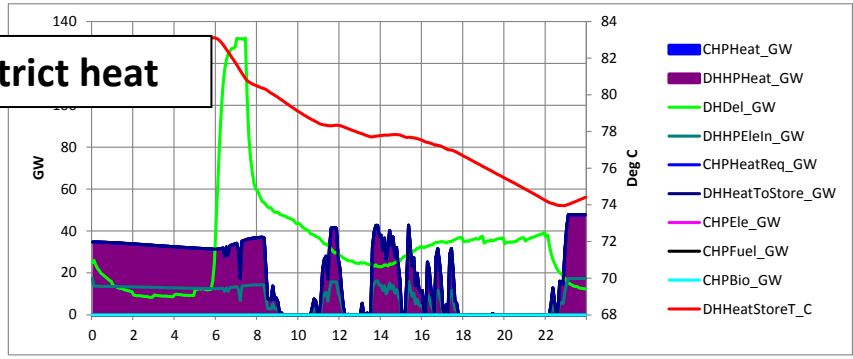


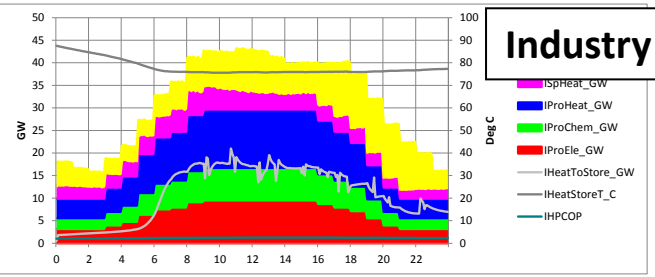
A national energy system

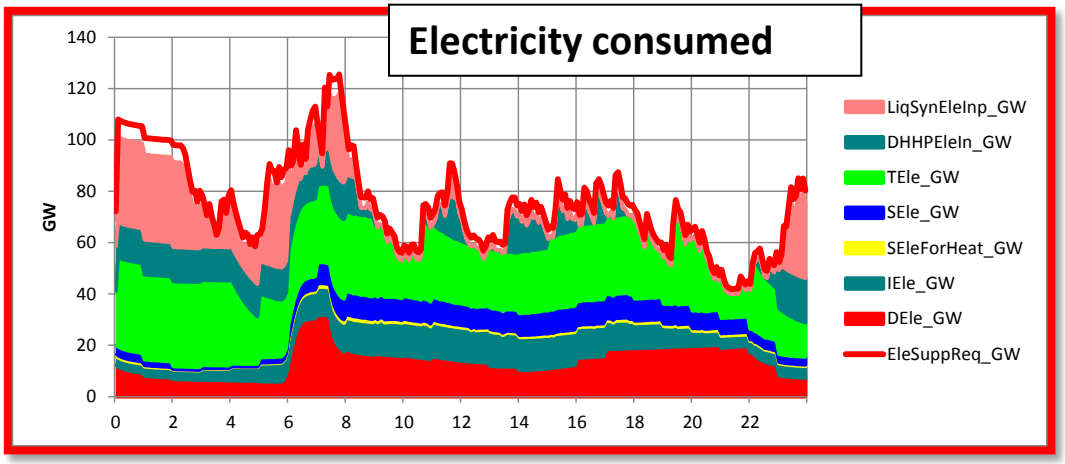


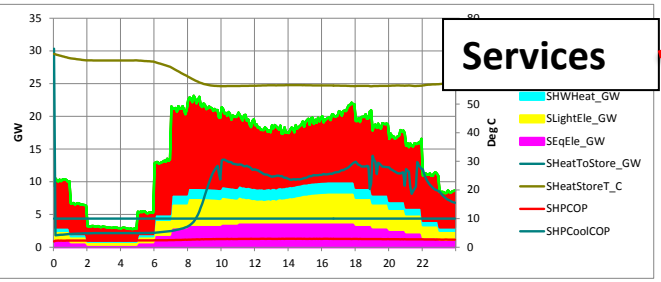
Energy consumption – DynEMo one day for month 1 ; modelled at 5 min intervals

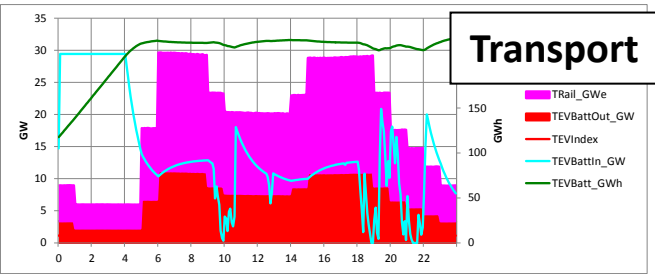


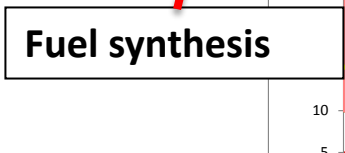


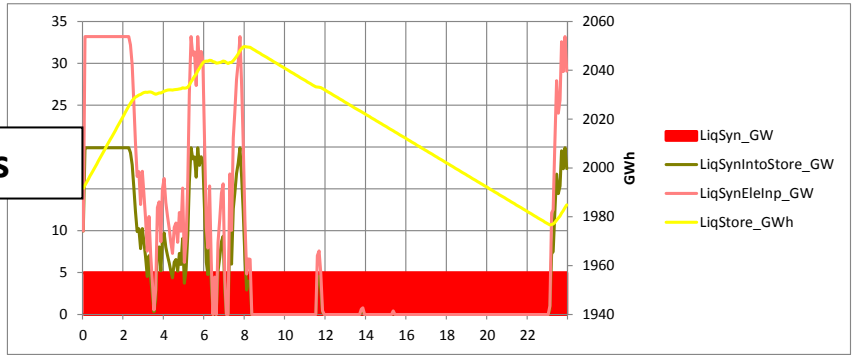






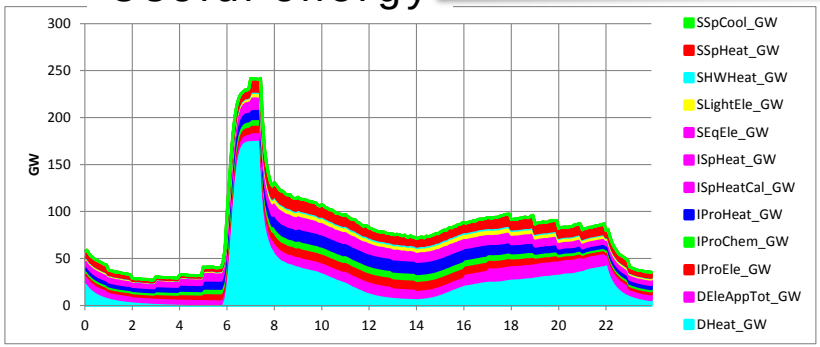






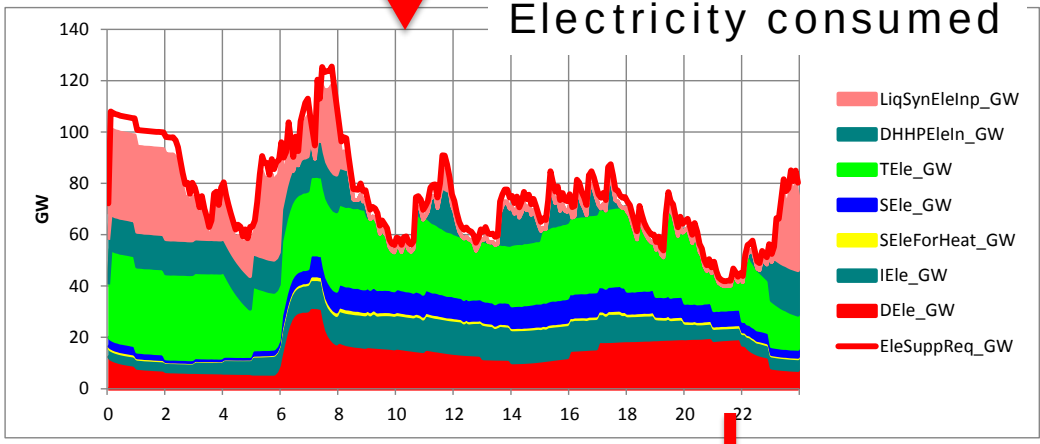
Matching demand to supply – DynEMo 1 day for months 1 ; modelled at 5 min intervals

Useful energy

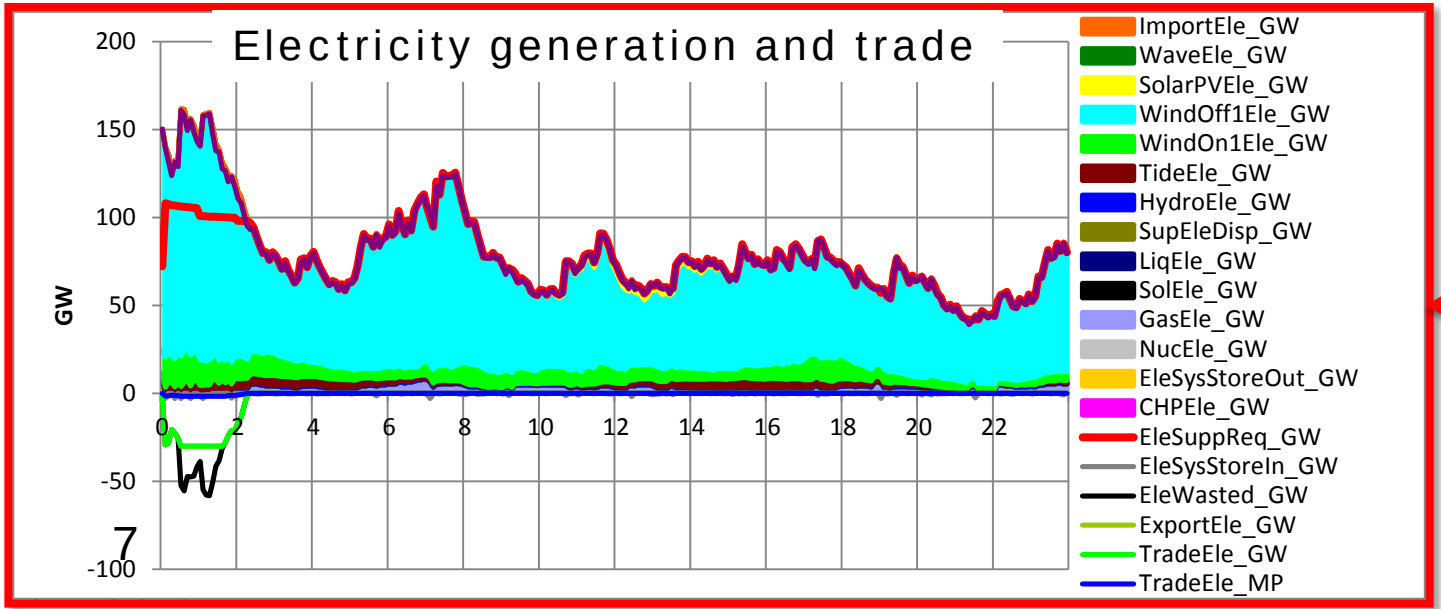


Storage

Electricity consumed

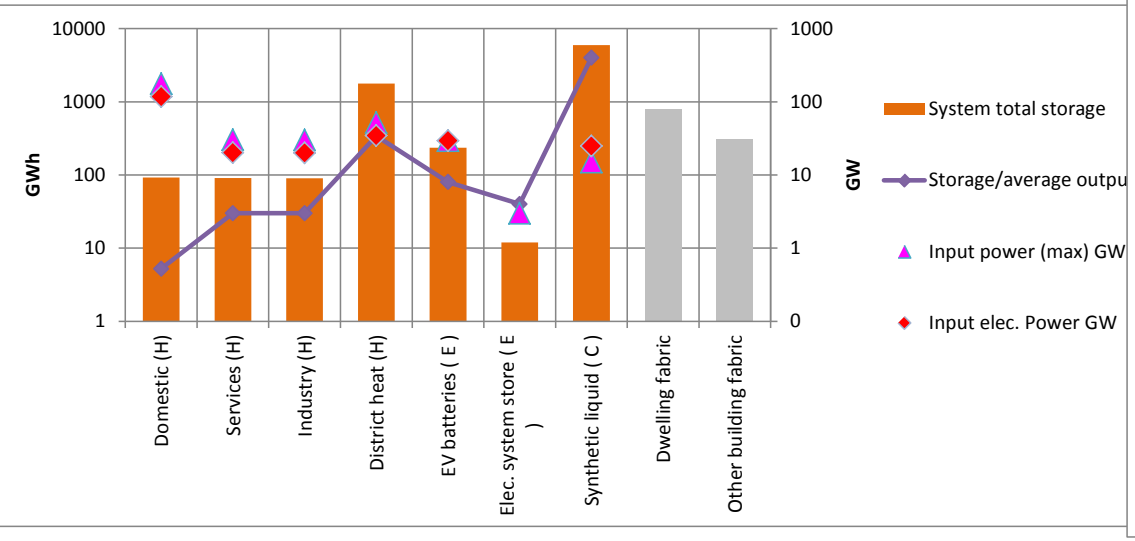


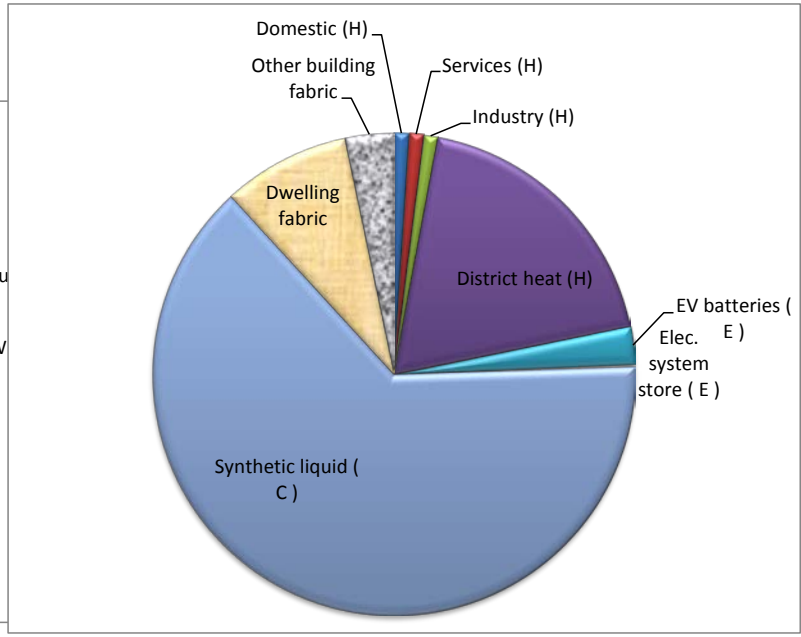
Electricity generation and trade



Energy Space Time

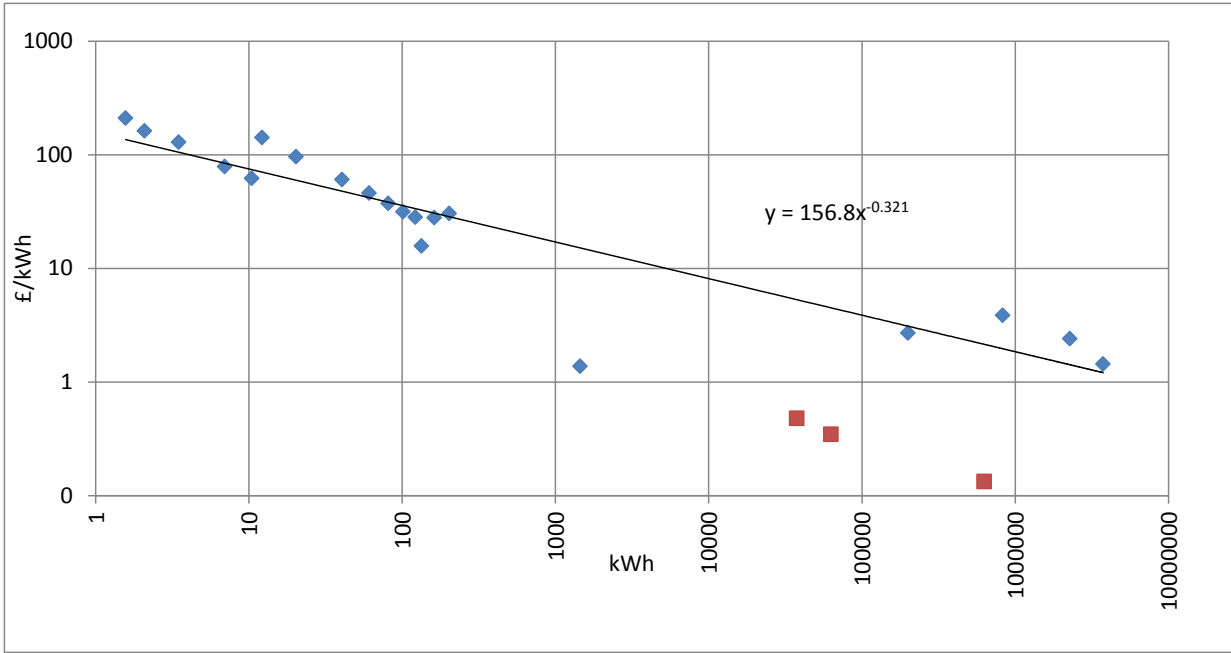
National system – storage



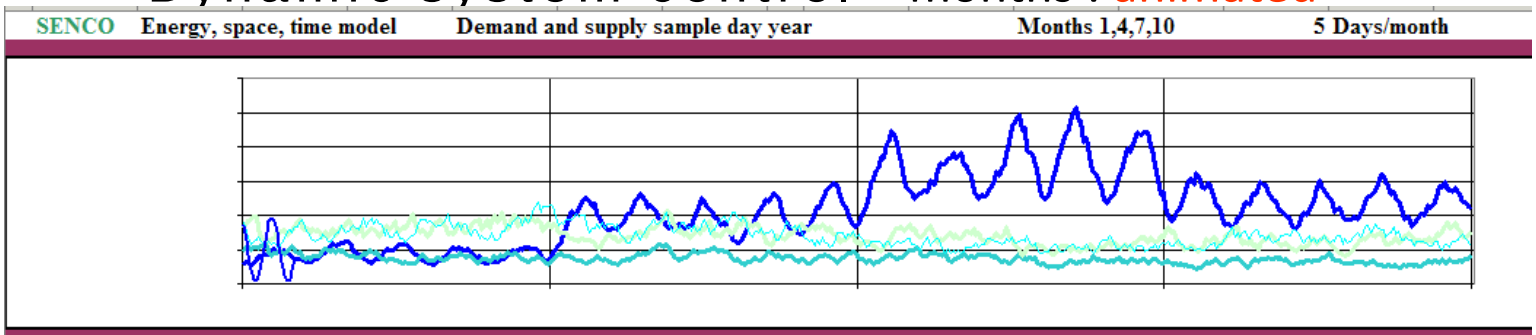


Heat storage scale economies

District heat store ~ 100x lower cost (£/kWh) than domestic scale

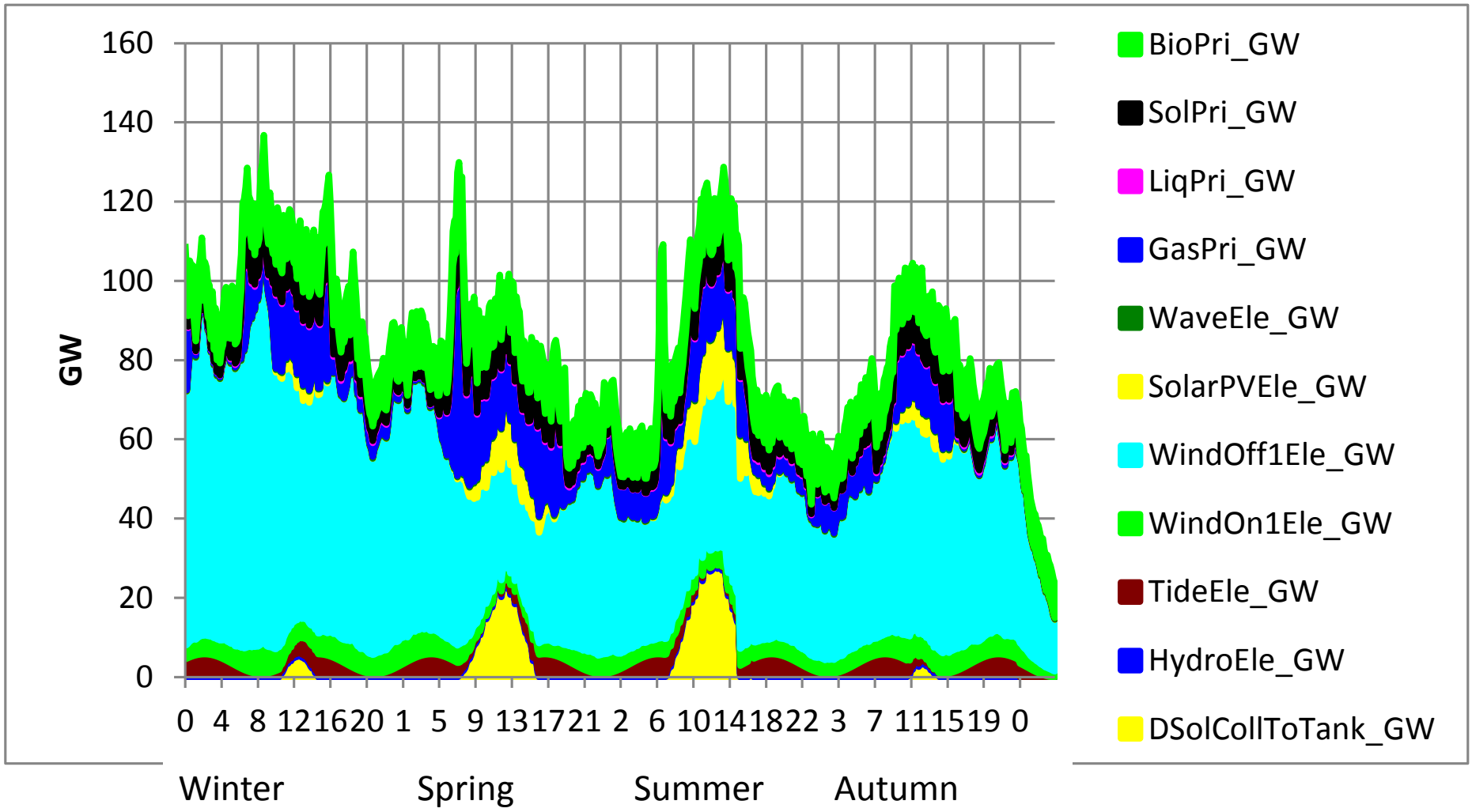


Dynamic system control – months : animated



Primary supply :2050 – one day for months 1,4,7,10 ; modelled at 10 min intervals

Fossil/bio/hydro generation highly variable.



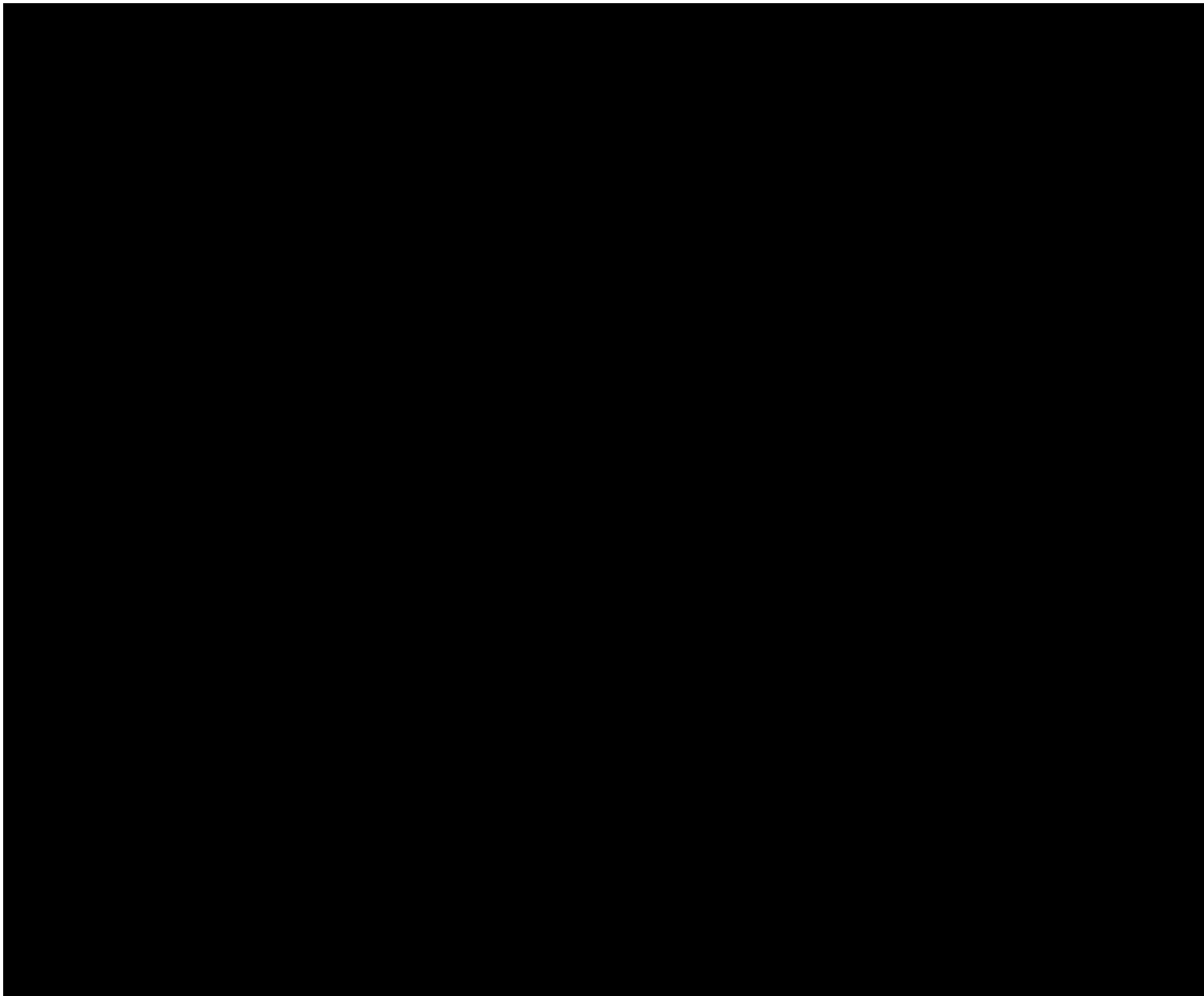
Energy trade

100 years development

Electricity trade optimisation illustration

Two way trade with imports and exports at different times depending on net of demand and renewables at nodes.

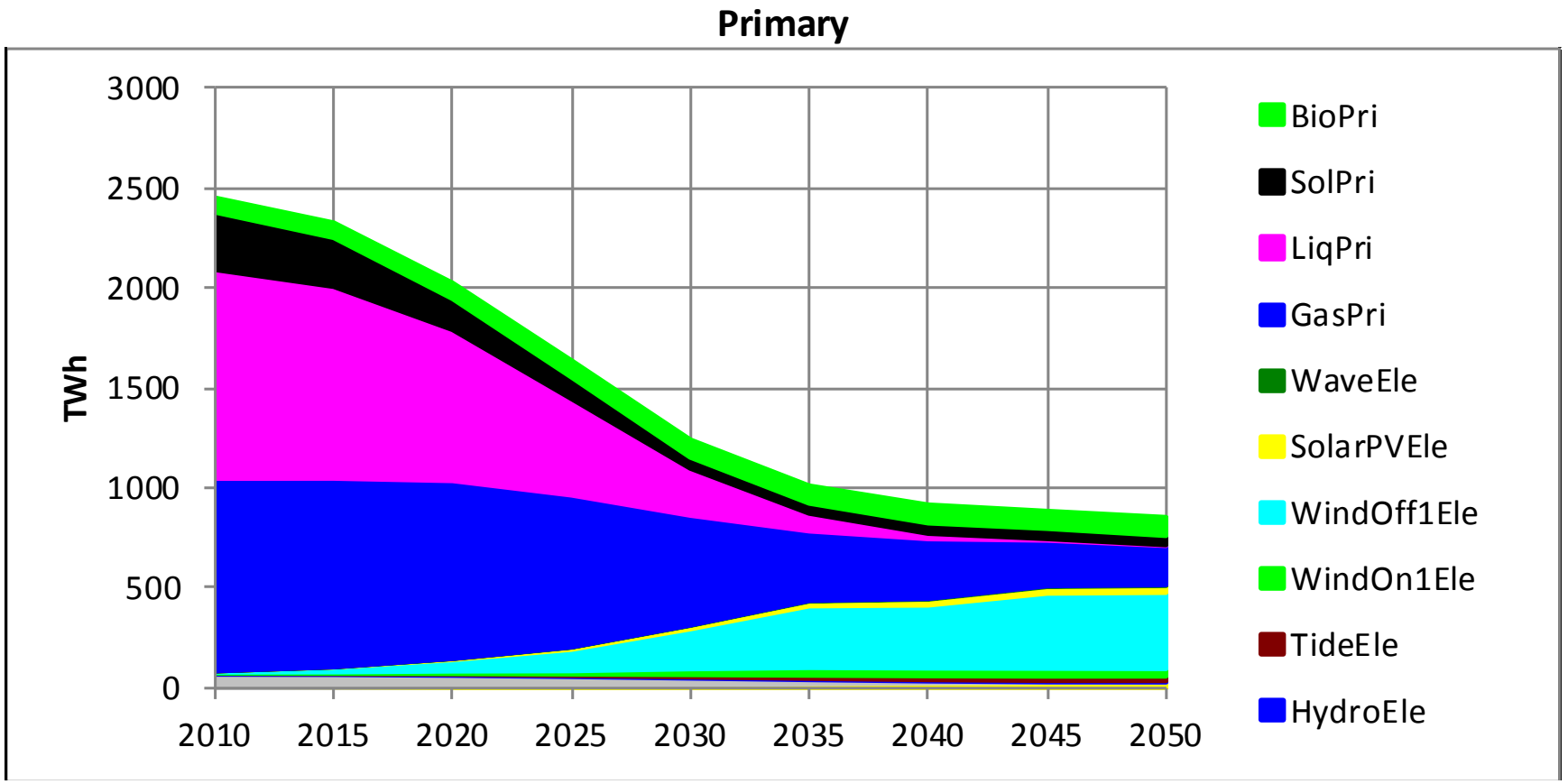
Exchange enhances political security.



Scenario primary energy

Scenario: UD1:UB1:UE1:US1:PE1:PS1

Still significant fossil gas use. Reduce with more storage, more trade, more dispatchable low carbon supply (e.g. biomass, renewable hydrogen/ammonia).



City resource sinks and renewable facilitators

The resource system comprises:

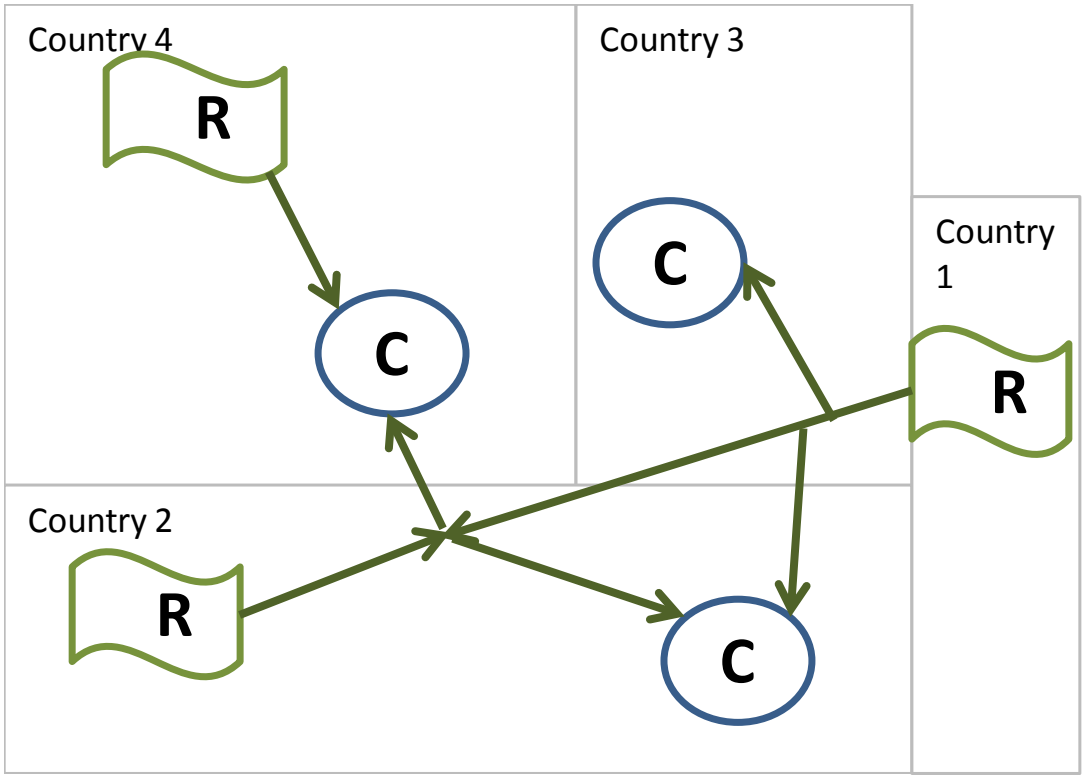
- **Demand (mainly cities)**
- **Resources**
- **Transmission**

The spatiotemporal geography of cities and external resources is basic to the design of physical systems with resource vectors.

Optimal, least cost systems will not generally respect national boundaries.

But national boundaries will impact on design through security concern.

How do we model and design this system, and develop policy?



C-cities R - resources

City energy, environment and economic model

Innovate funded model development 2015-2017 application led by Energy Saving Trust, model by UCL

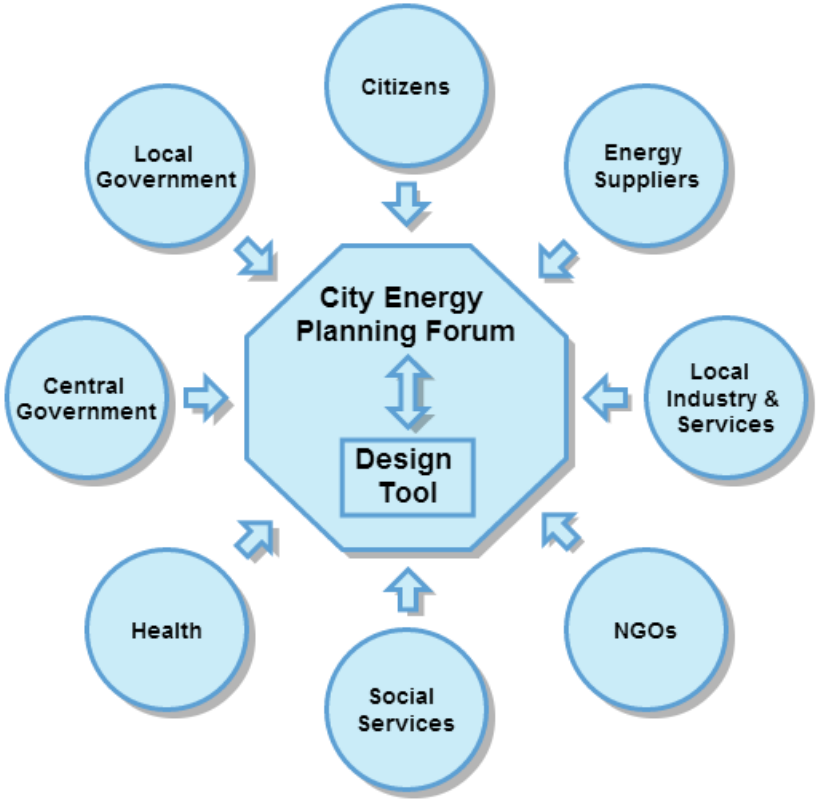
Aid planning and implementation by stakeholders using data and modelling design tools. Applicable to any city.

First phase asked cities what they want.

Answers:

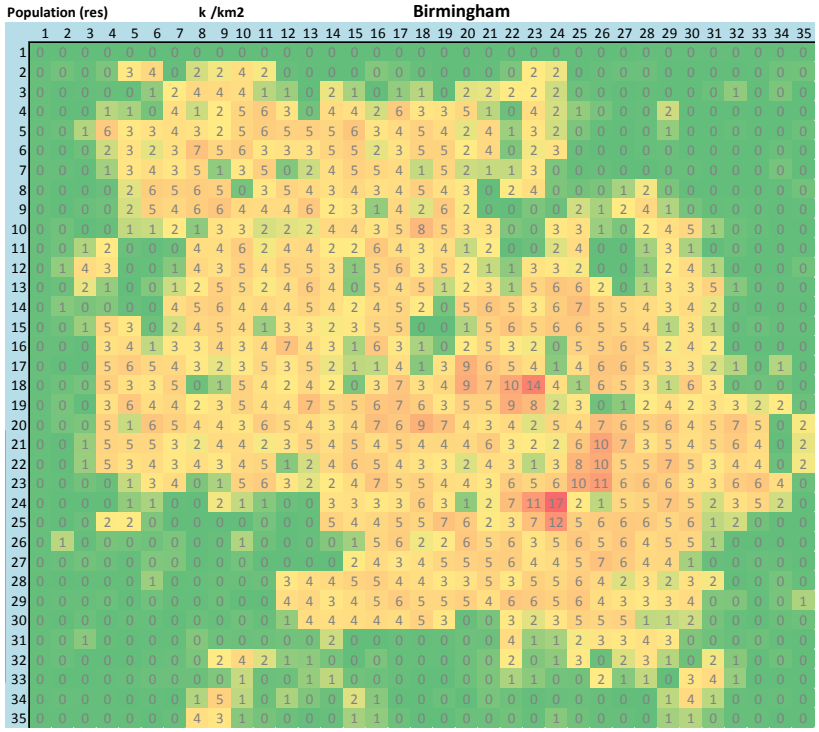
- Fuel poverty relief
- Reduced emissions
- Energy efficiency
- City energy supply
- Reduced city energy costs
- Use model with city stakeholders to aid implementation of:

Develop with pilot cities and then apply to others

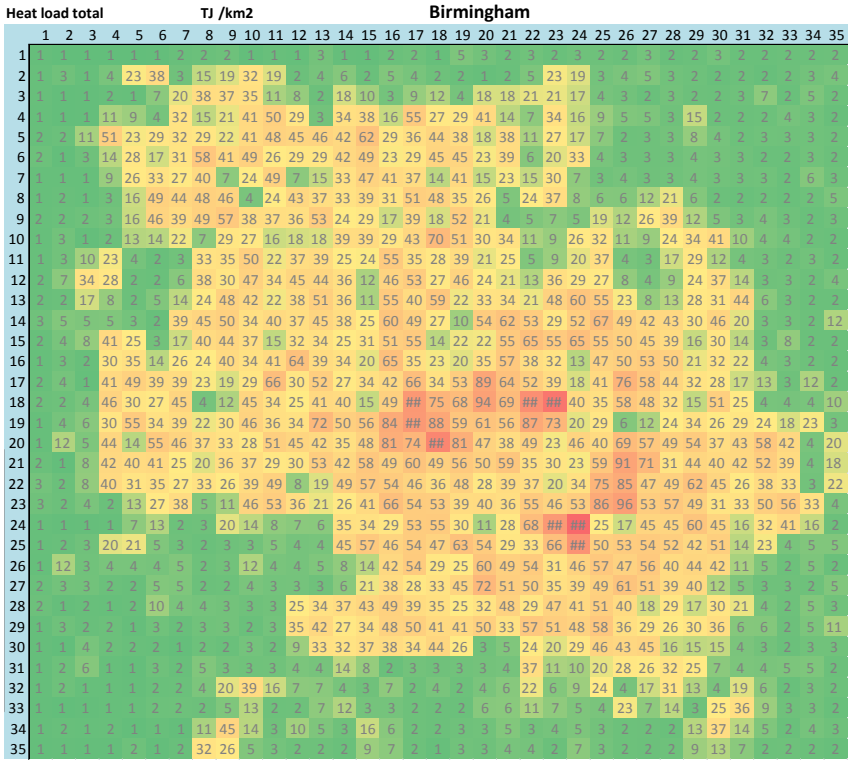


City population and heat load (illustration)

Population

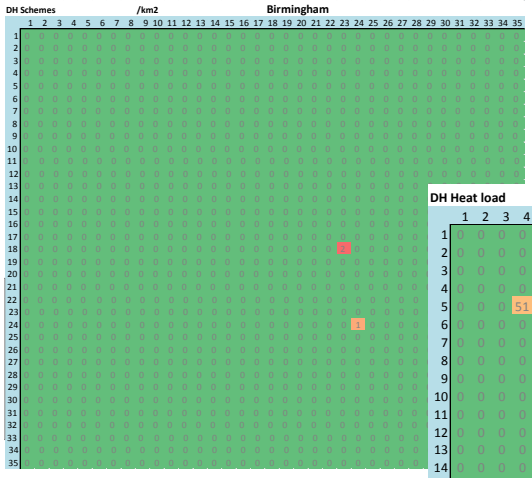


Heat load

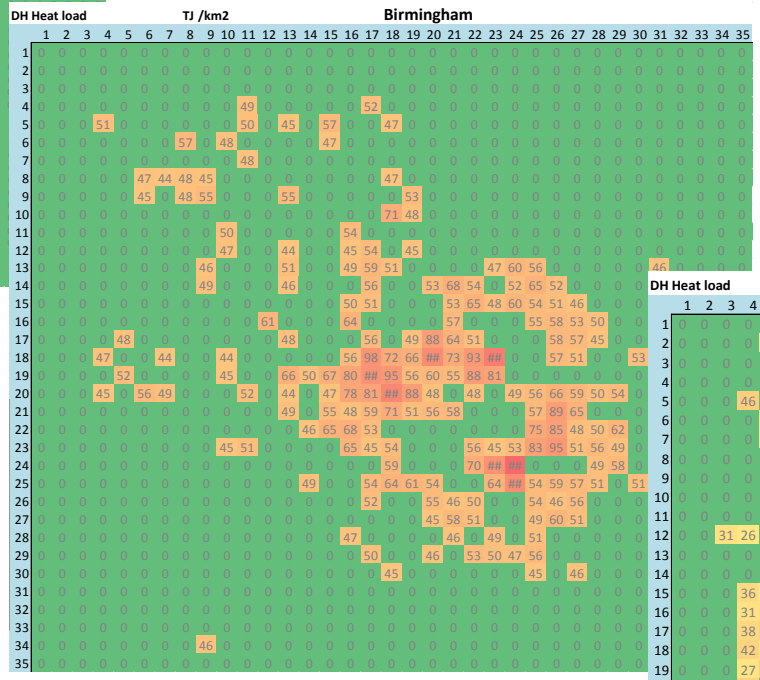


City district heating with heat pumps and CHP (illustration)

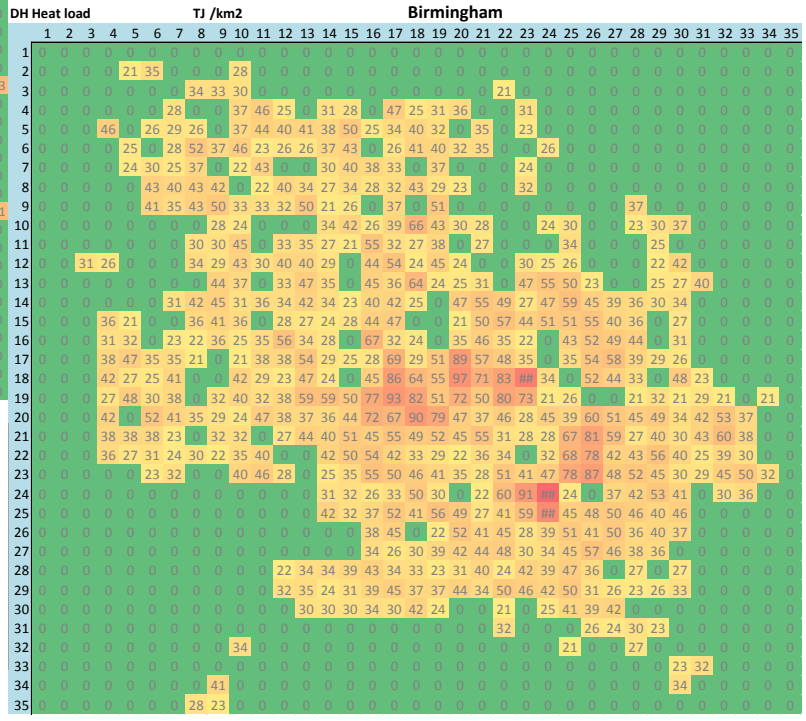
2015



2035?



2050?



City district heating with heat pumps and CHP (illustration)

				Scheme				Individual=>			
				City	1	2	3	4	5	6	7
Scheme size		Consumers	k	2329	2271	7	7	12	4	16	11
		Heat: annual	TJ	20658	20189	57	56	94	34	140	88
		Heat: peak	MW	11644	11355	36	36	59	22	82	55
		Pipe length	km	5270	5110	20	20	30	10	50	30
		Storage	MWh	139732	######	431	429	707	260	981	662
		CHP	MW	2911	2839	9	9	15	5	20	14
		Heat pump	MW	5822	5678	18	18	29	11	41	28
		Boiler	MW	9315	9084	29	29	47	17	65	44
Heat	**losses**		TJ	3099	3028	8	8	14	5	21	13
	total required		TJ	23757	23218	65	64	108	39	161	102
	Output	CHP	TJ	10691	10448	29	29	49	17	73	46
		Heat pump	TJ	10691	10448	29	29	49	17	73	46
		Boiler	TJ	2376	2322	6	6	11	4	16	10
	Fuel in	CHP	TJ	23757	23218	65	64	108	39	161	102
		Heat pump	TJ	3564	3483	10	10	16	6	24	15
		Boiler	TJ	2795	2732	8	8	13	5	19	12
	Elec out	CHP		9503	9287	26	26	43	16	65	41
Capital	**Unit**	Connection/meter	£/bldg	2500	2500	2500	2500	2500	2500	2500	2500
		Pipe	£/m	1200	1200	1200	1200	1200	1200	1200	1200
		Storage	£/kWh	2	2	18	18	14	22	13	15
		CHP	£/kW	676	677	1205	1205	1146	1267	1109	1154
		Heat pump	£/kW	250	250	397	397	381	413	372	383
		Boiler	£/kW	48	48	76	76	73	80	72	74
	Total	Connection/meter	M£	2531	2469	8	8	13	5	18	12
		Pipe	M£	6324	6132	24	24	36	12	60	36
		Storage	M£	244	241	8	8	10	6	12	10
		CHP	M£	1967	1923	11	11	17	7	23	16

		Storage	MWh	139732	######	431	429	707	260	981	662
		CHP	MW	2911	2839	9	9	15	5	20	14

City district heating with heat pumps and CHP (illustration)

	total required		TJ	23757	23218	65	64	108	39	161	102
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Capital	**Unit**	Connection/meter	£/bldg	2500	2500	2500	2500	2500	2500	2500	2500
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		Storage	£/kWh	2	2	18	18	14	22	13	15
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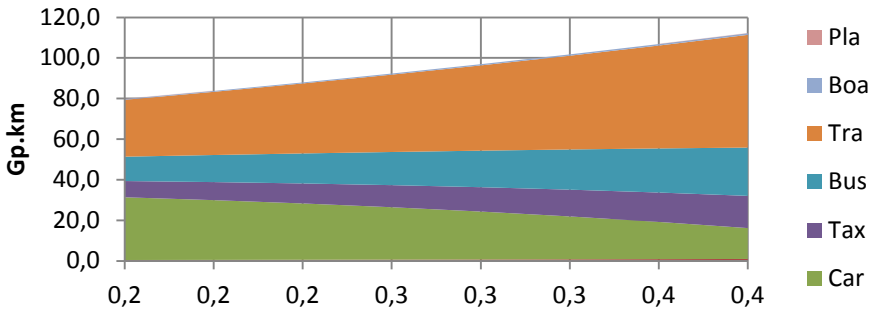
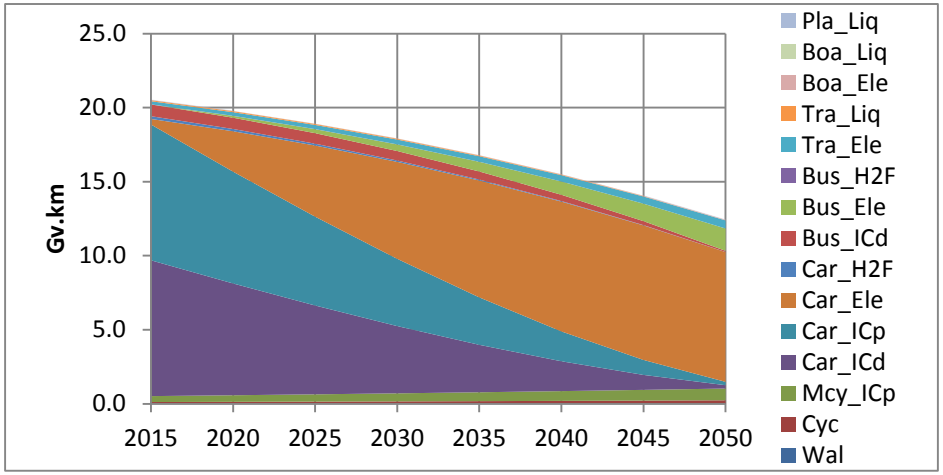
	Total	Connection/meter	M£	2531	2469	8	8	13	5	18	12
		Pipe	M£	6324	6132	24	24	36	12	60	36
		Storage	M£	244	241	8	8	10	6	12	10
		CHP	M£	1967	1923	11	11	17	7	23	16
		Heat pump	M£	1455	1422	7	7	11	4	15	11
		Boiler	M£	448	438	2	2	3	1	5	3
		Total capital	M£	**12970**	**12624**	**60**	**59**	**91**	**35**	**133**	**88**
		Annual	M£/a	**1086**	**1057**	**5**	**5**	**8**	**3**	**11**	**7**
Fuel	**Costs**	CHP	M£/a	3421	3343	9	9	16	6	23	15
		Heat pump	M£/a	1283	1254	4	3	6	2	9	5
		Boiler	M£/a	402	393	1	1	2	1	3	2
		CHP elec	M£/a	-3801	-3715	-10	-10	-17	-6	-26	-16
		Total fuel	M£/a	**1305**	**1276**	**4**	**4**	**6**	**2**	**9**	**6**
		Total annual	M£/a	**2392**	**2333**	**9**	**8**	**14**	**5**	**20**	**13**
Heat cost		**Capital**	£/GJ	0.05	0.05	0.09	0.09	0.08	0.09	0.08	0.08
per unit		**Fuel**	£/GJ	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
		Total	£/GJ	0.12	0.12	0.15	0.15	0.14	0.15	0.14	0.15
			p/kWh	3.2	3.2	4.2	4.2	4.0	4.2	4.0	4.1

City transport and emissions (illustration)

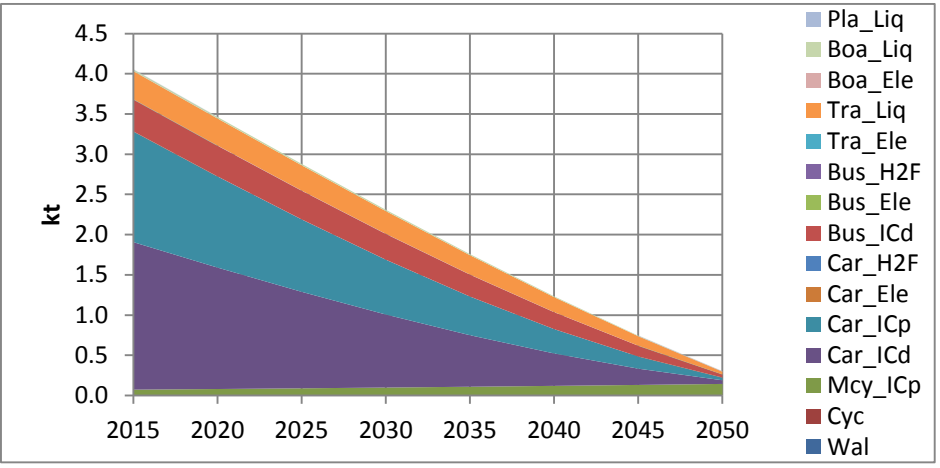
Passenger demand and mode



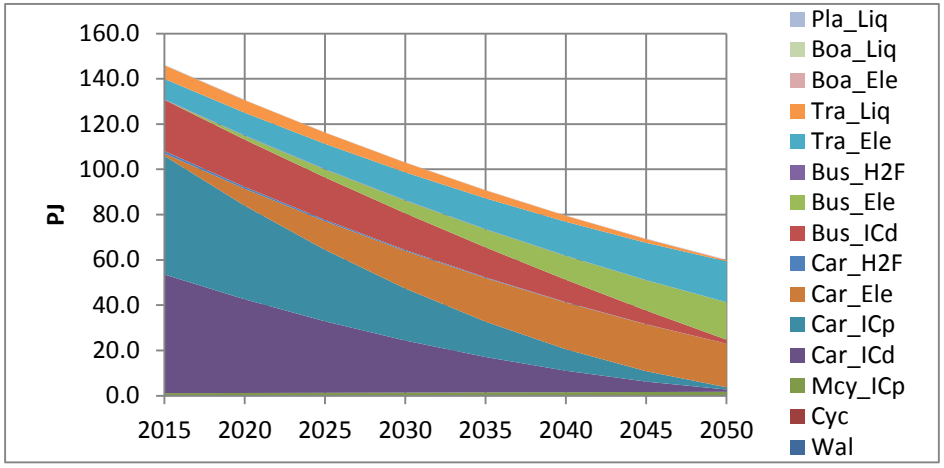
Vehicle distance



NOx emission



Vehicle energy



Thank you for listening.

Questions?