

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

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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

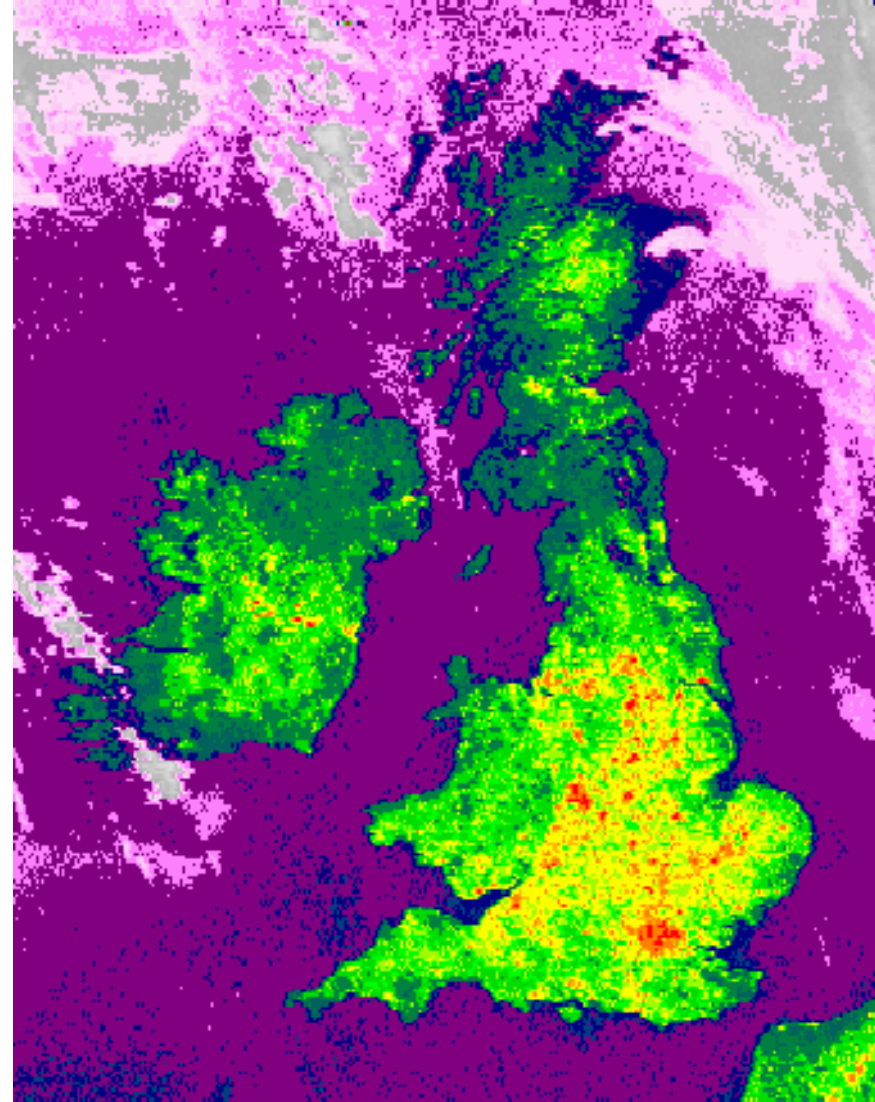
- Behavioural
- Technical

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 Water

Light Space

Process

Incomes

Sun Tide

Hydro

Wind

Wave

Converters

Generators

Optional Income

PS Solar

Hydro

Wind

Wave

Tide

CHP

Stores

In/out Out

Gas Gas

Liquid Oil

Solid Coal

Elec

Heat

Transmission

Electricity

Gas

Heat

Liquid

EneModSpaceTime.xls:3

EneModSpaceTime.xls:4

SENCO Energy, space, time model Dummy data Year: 2025 August Hour: 24

EneModSpaceTime.xls:2

Demand and Converter flows, demands negative

Year: 2025 August Hour: 24

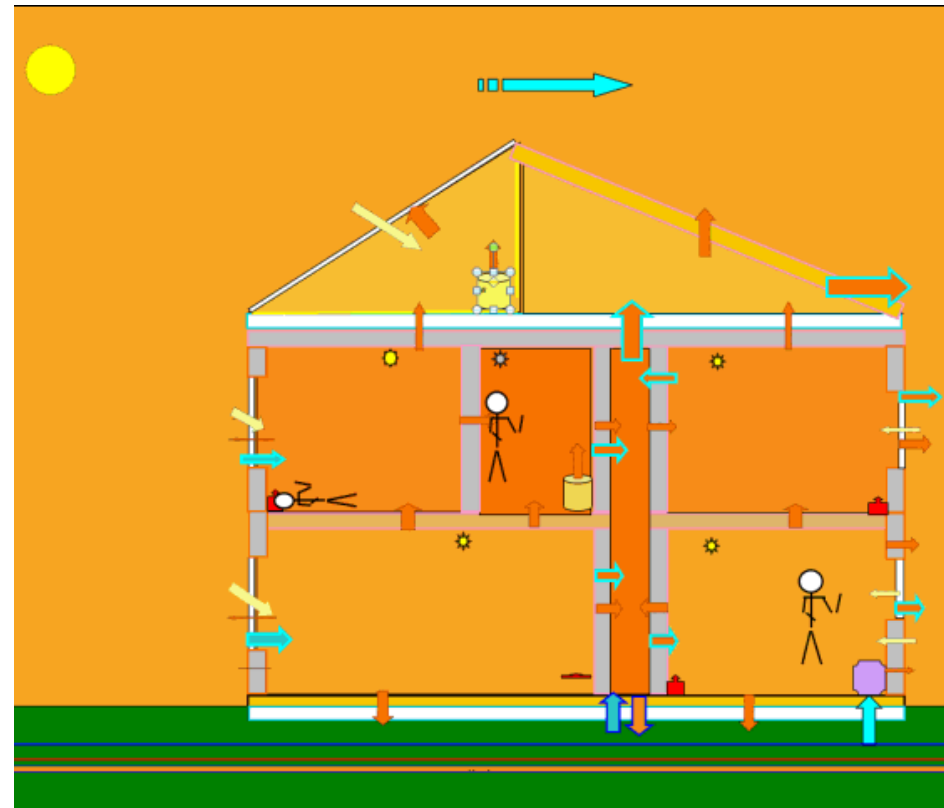
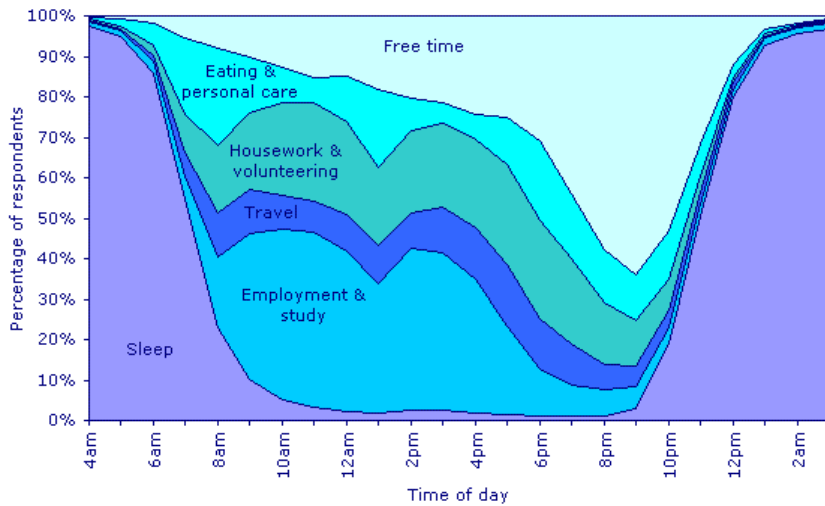
CHP, Income, Optional, and Demand

Legend: Optional (grey square), Income (green square), CHP (orange square), Demand (blue diamond)

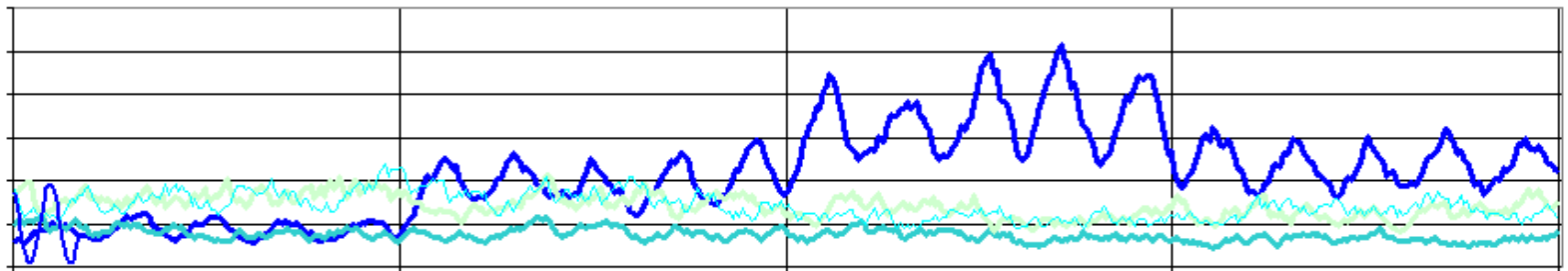
DynEMo Temporal drivers

Human use of time – UK

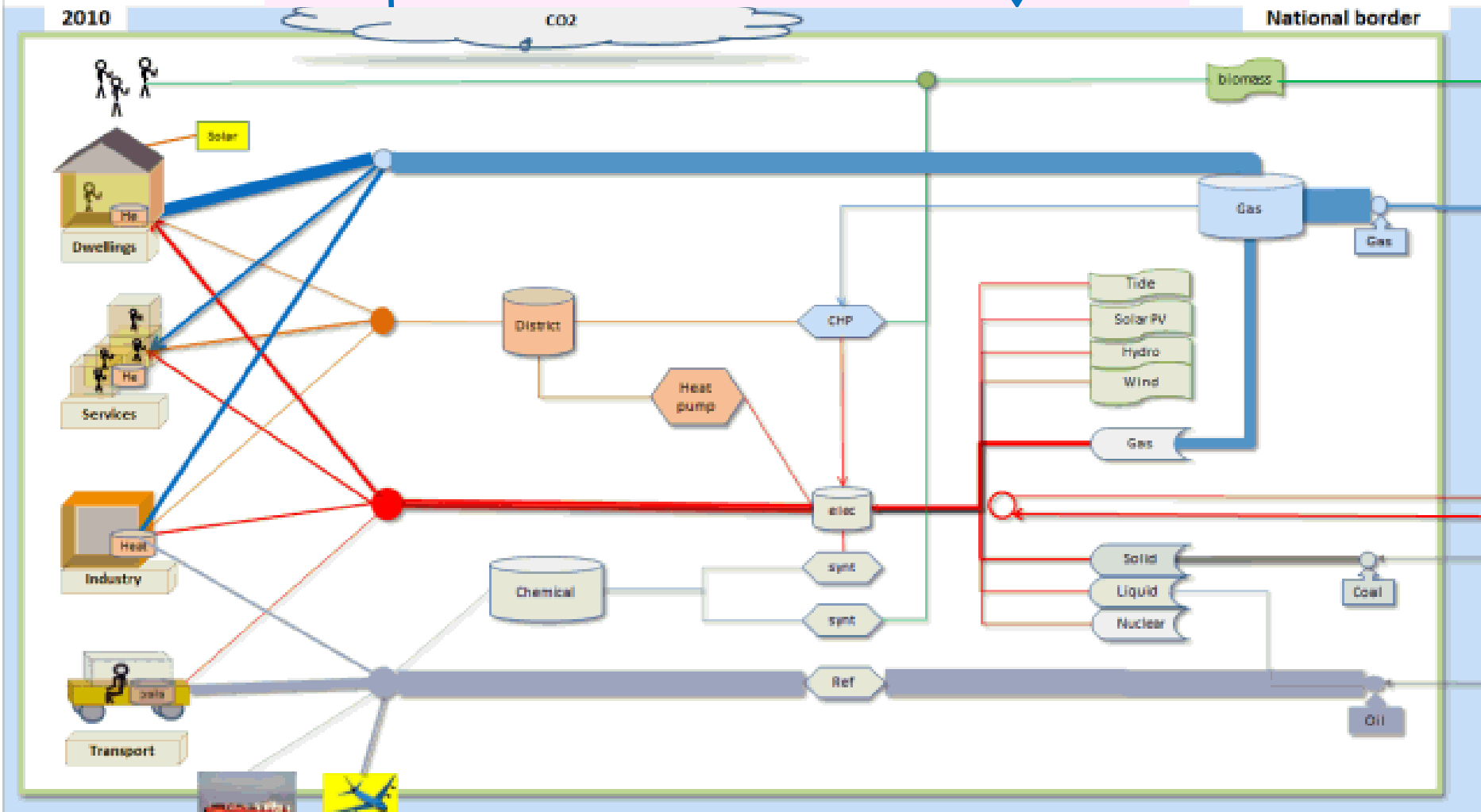
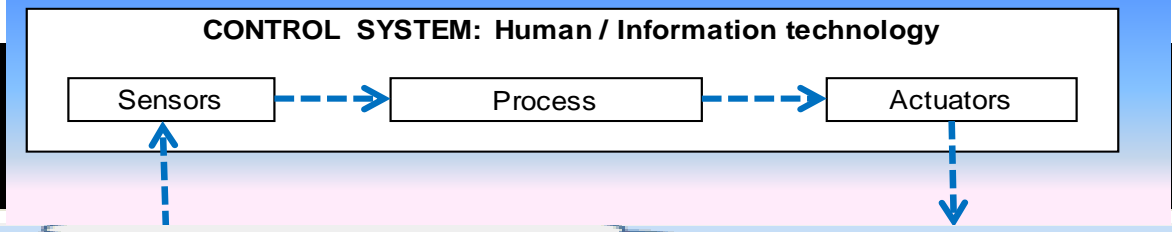
Quite invariable – a diurnal mammal!



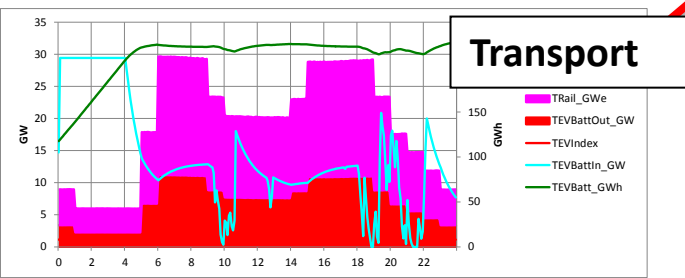
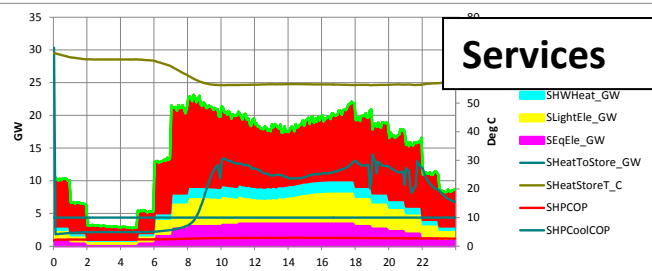
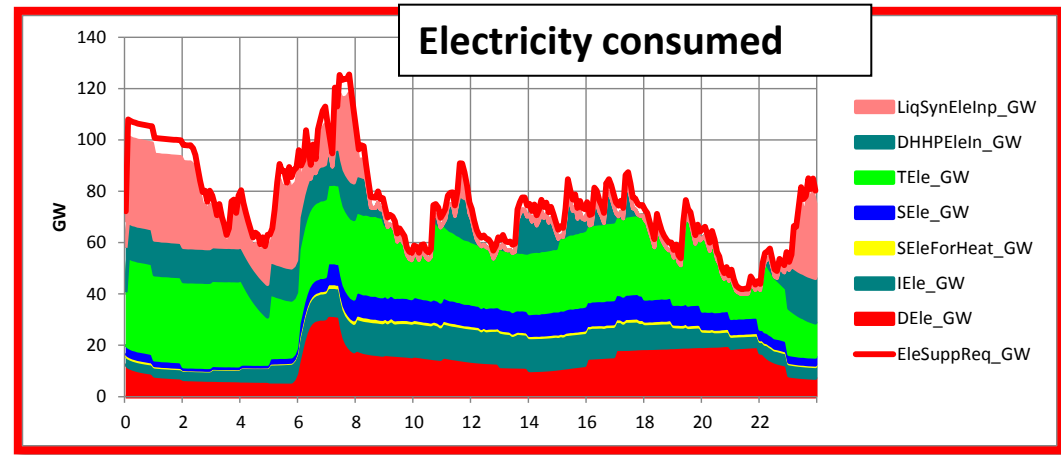
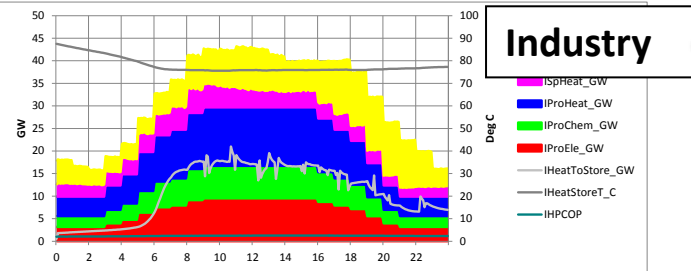
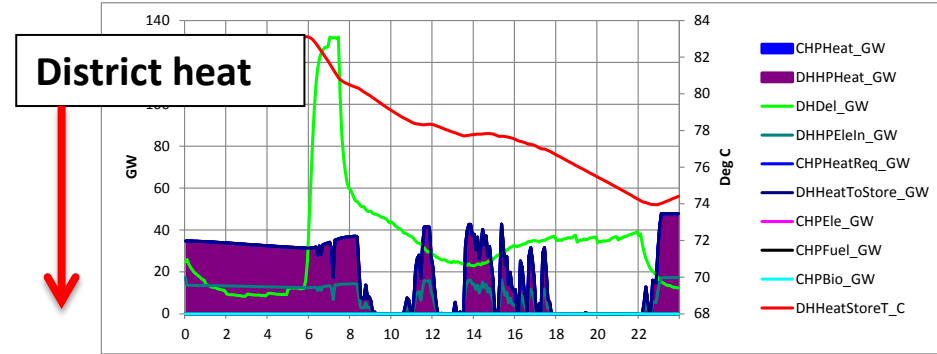
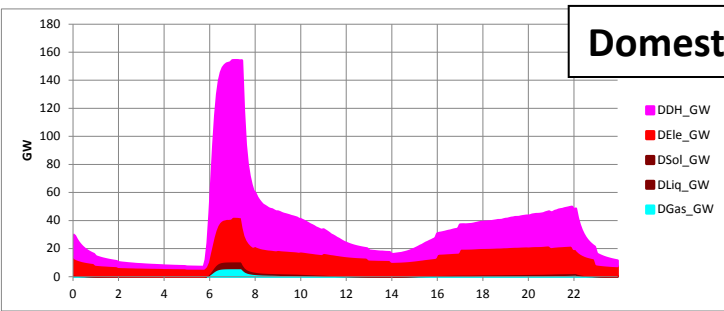
Weather and Renewables



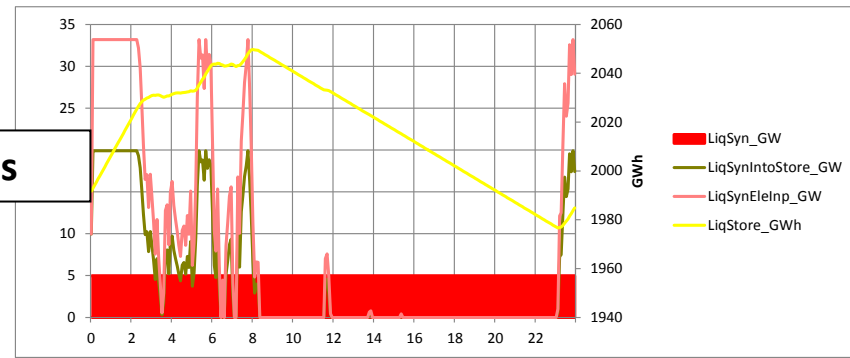
A national energy system



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

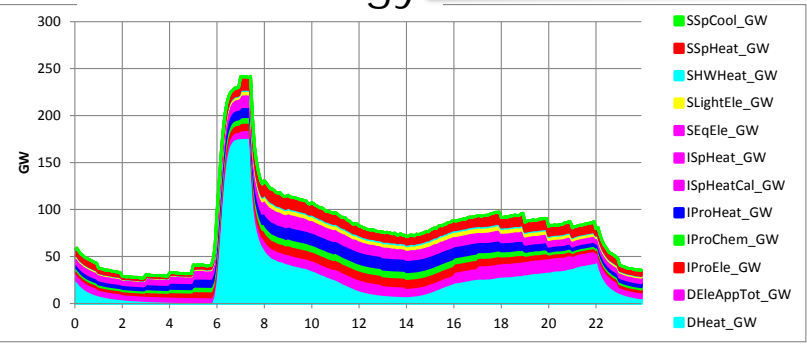


Fuel synthesis

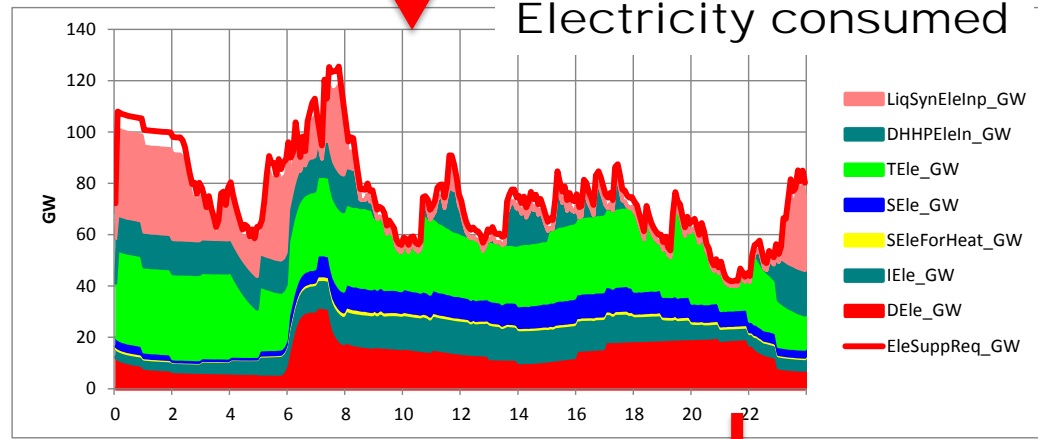


Matching demand to supply – DynEMo 1 day for months 1 ; modelled at 5 min intervals

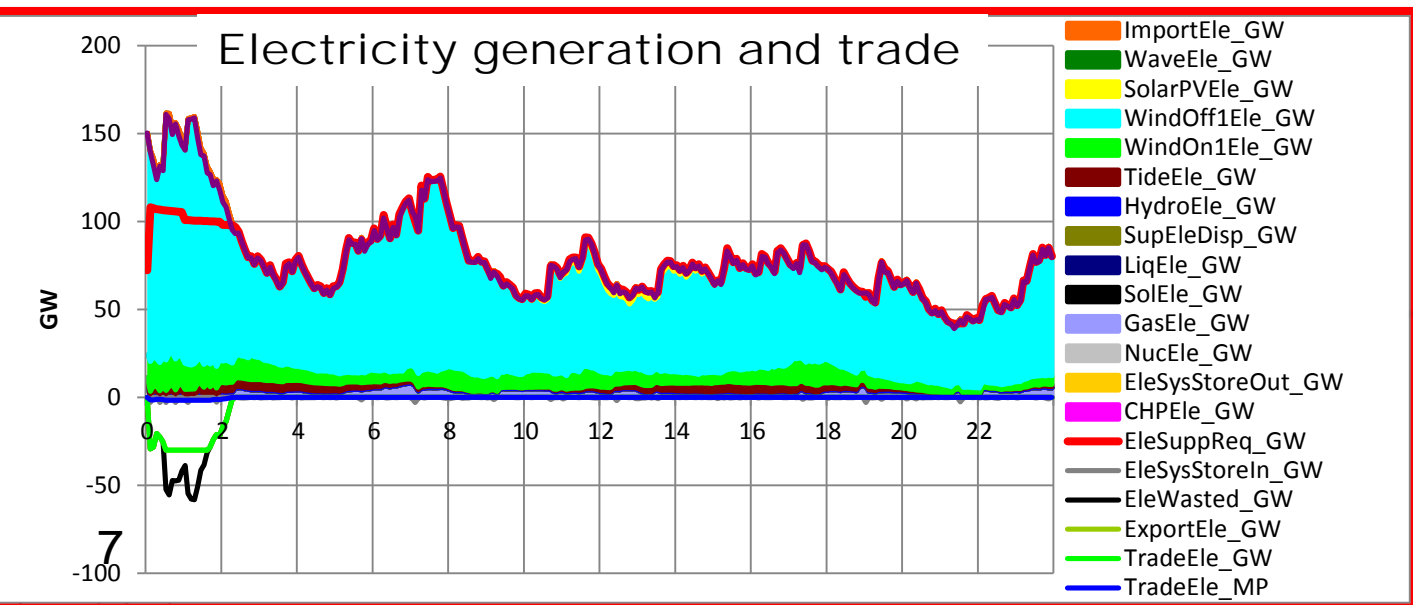
Useful energy



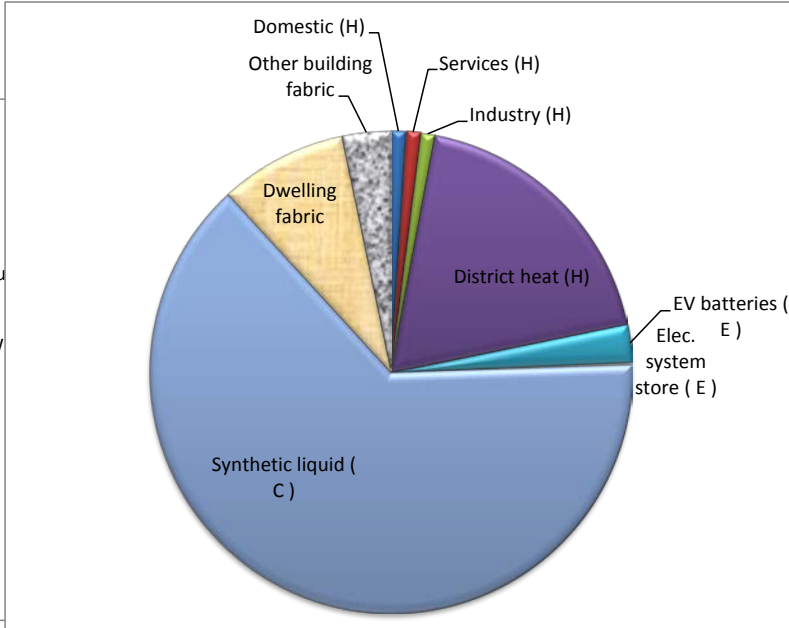
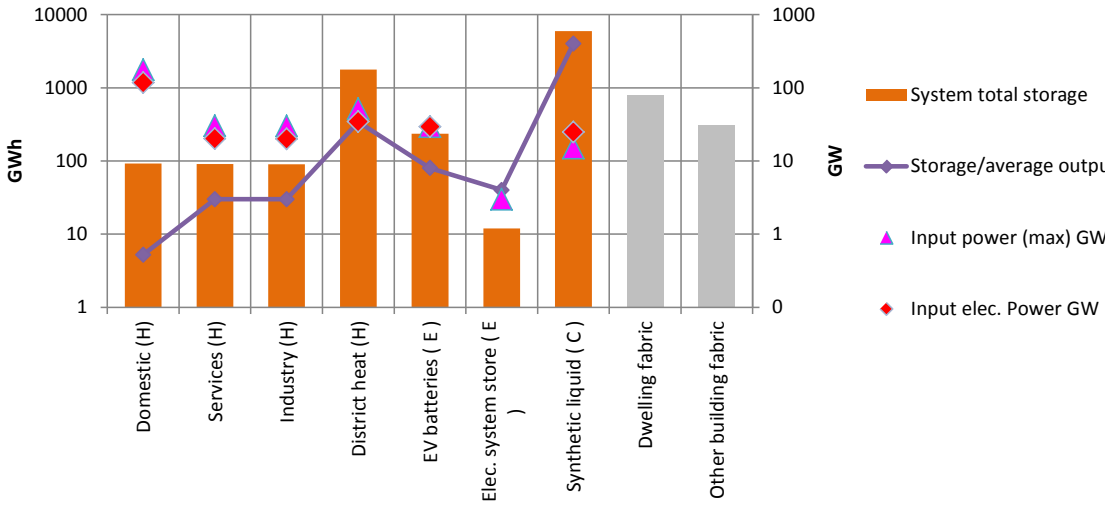
Electricity consumed



Electricity generation and trade

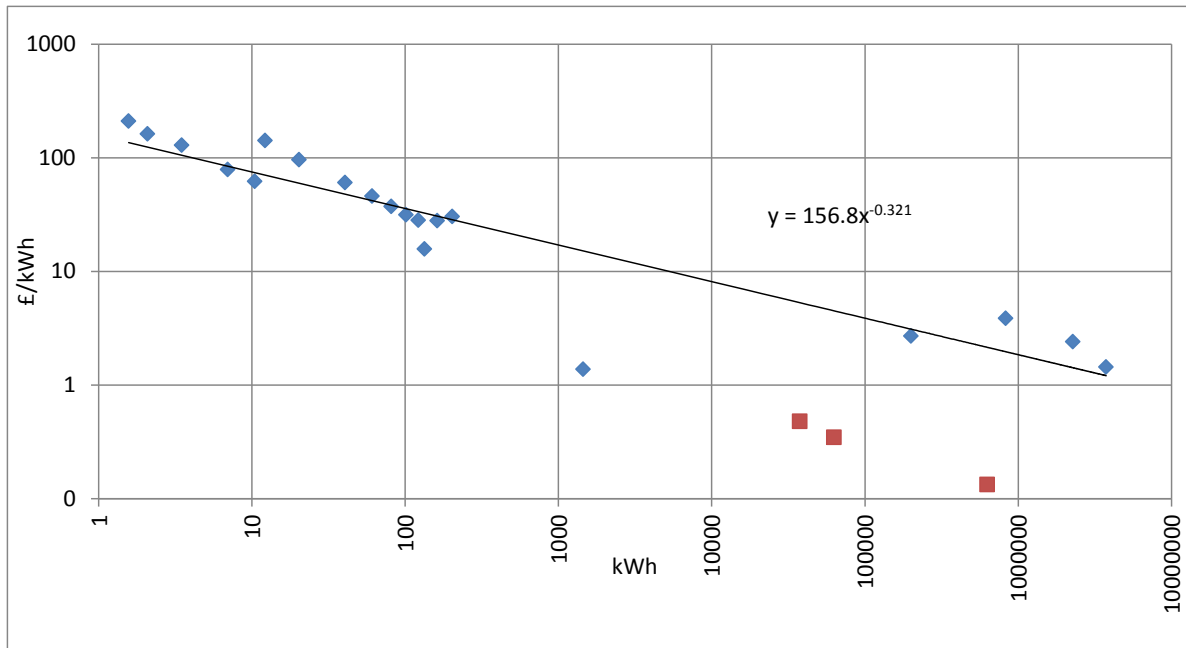


National system – storage



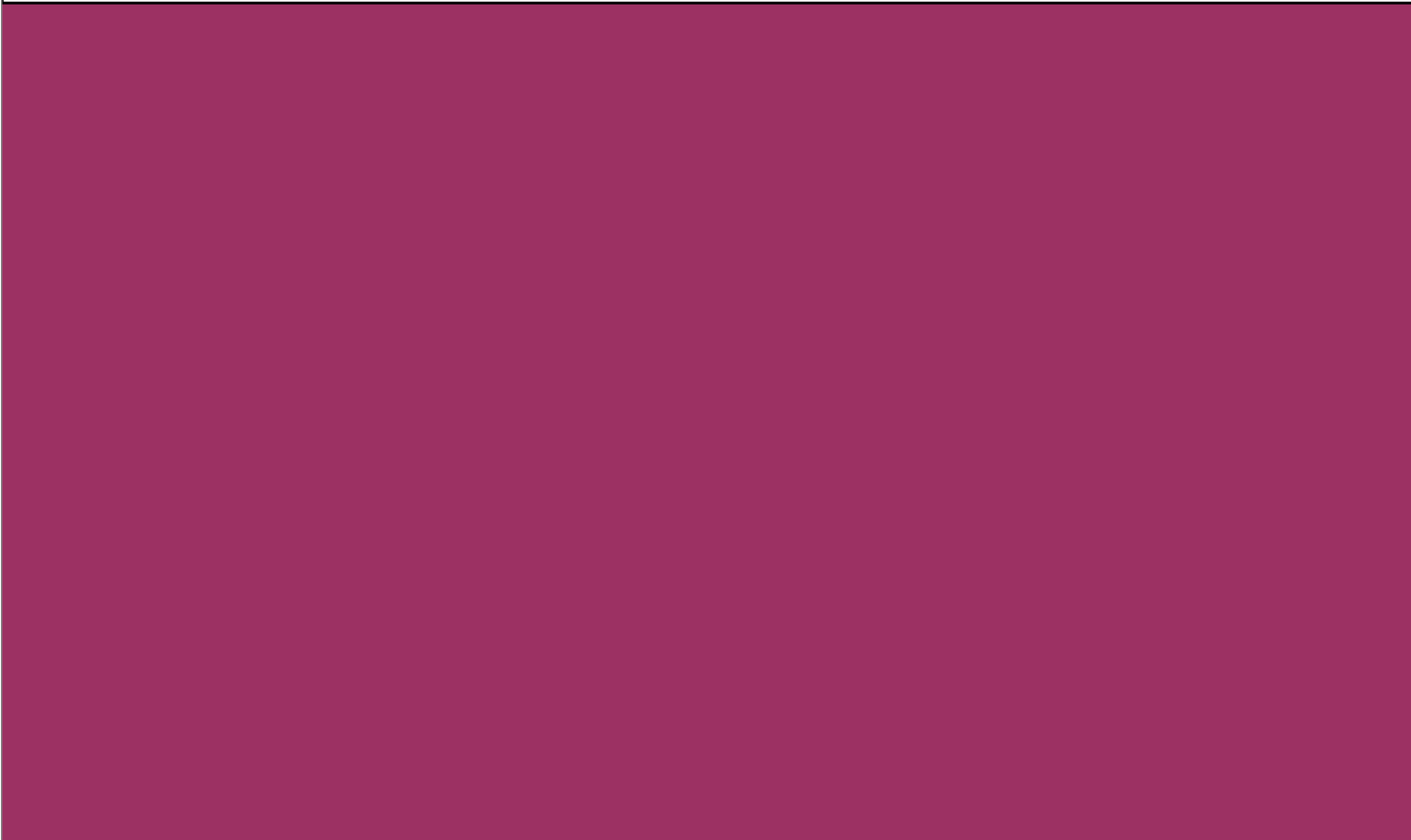
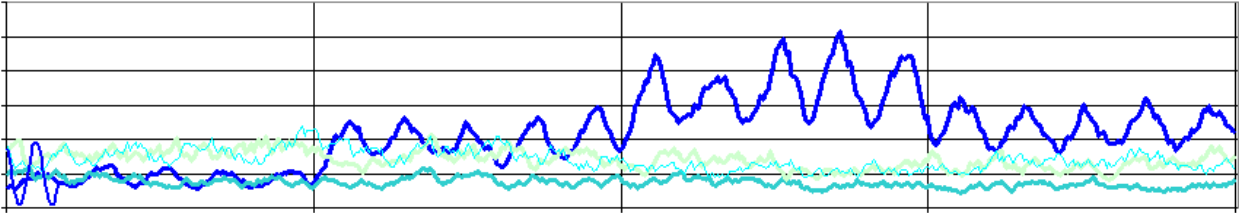
Heat storage scale economies

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

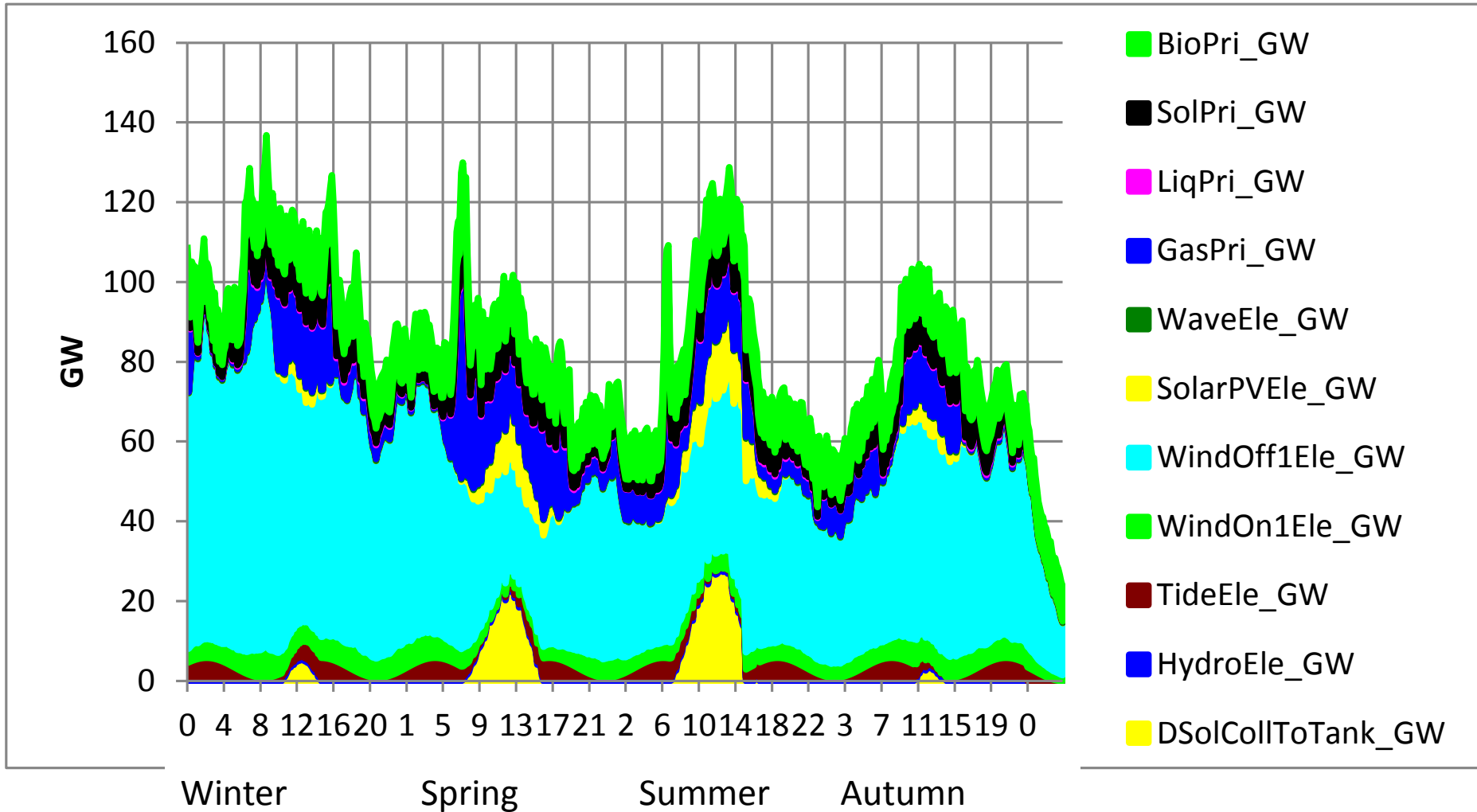


Dynamic system control – months : **animated**

SESCO Energy, space, time model Demand and supply sample day year Months 1,4,7,10 5 Days/month



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.

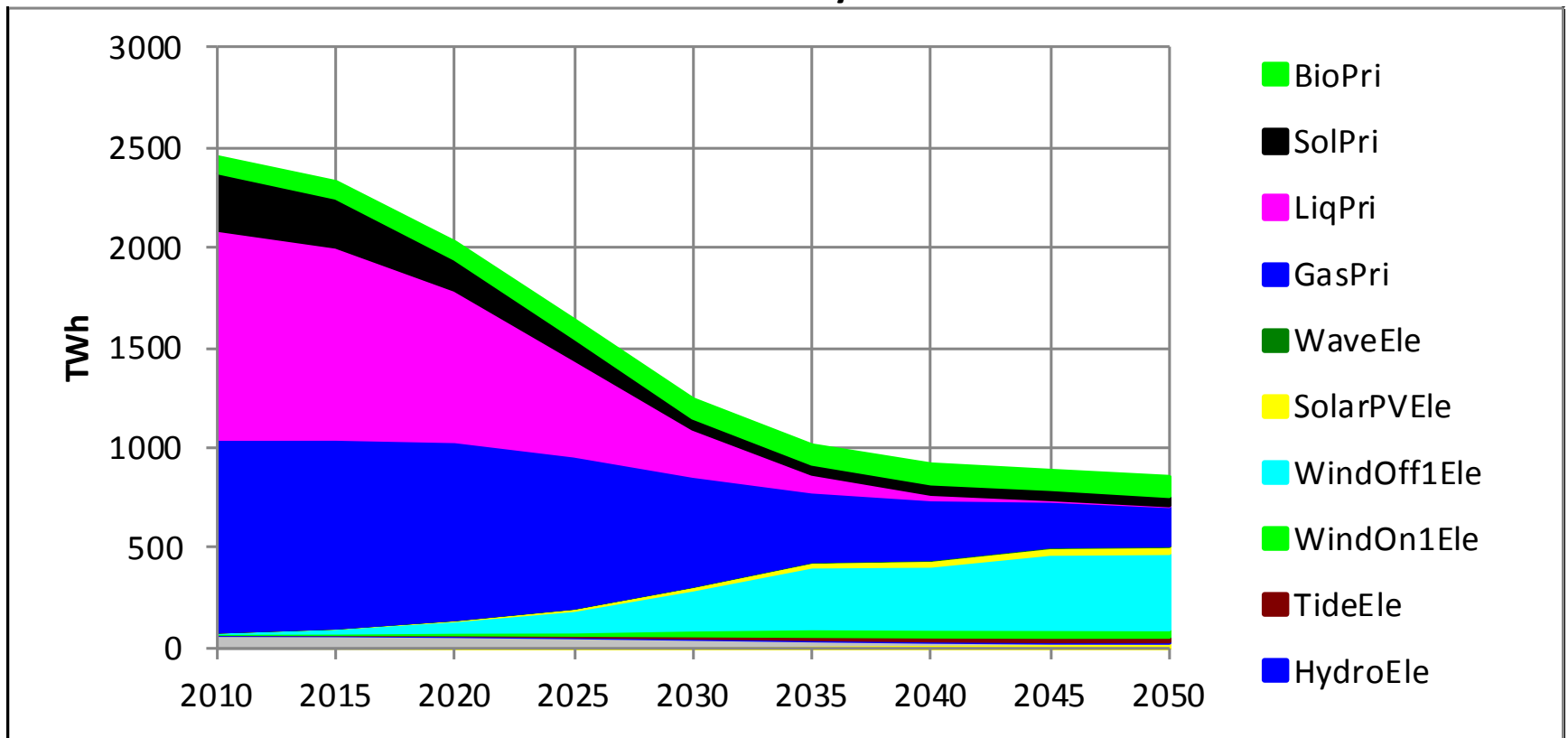
Exchange enhances
political security.

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).

Primary



City resource sinks and renewable facilitators

The resource system comprises:

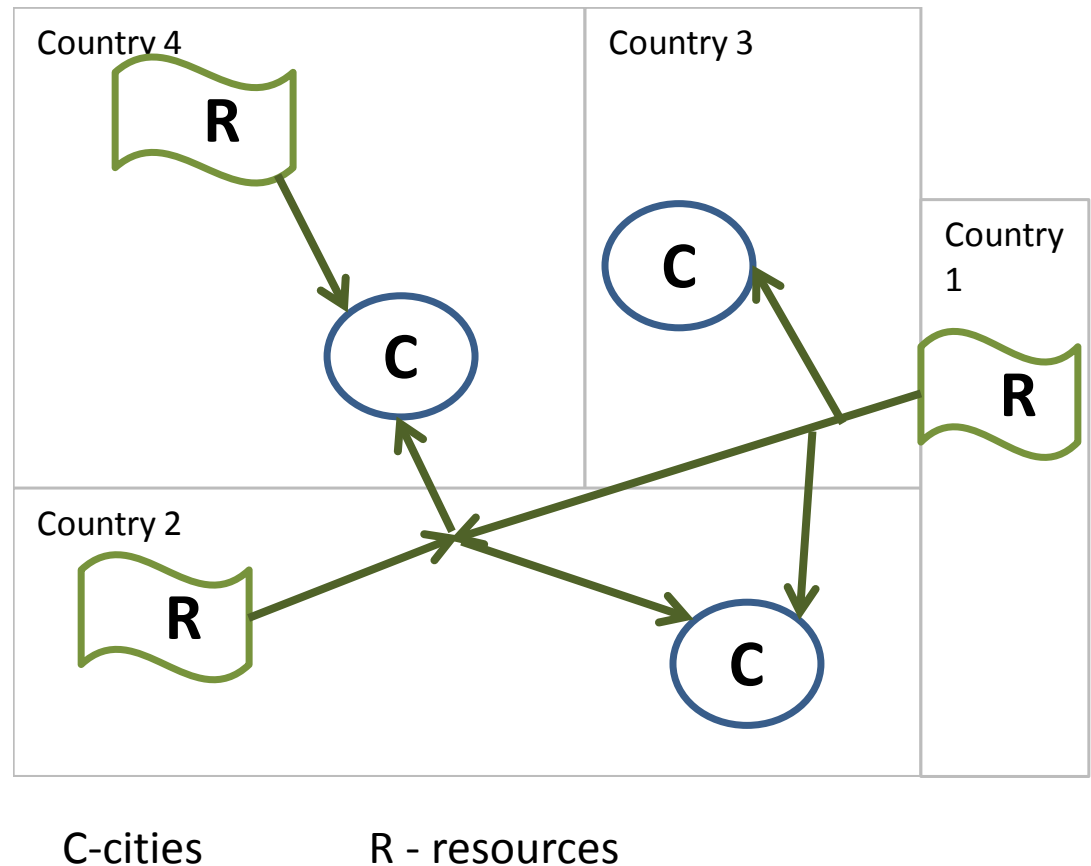
- Demand (mainly cities)
- Resources
- Transmission

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?



City energy, environment and economic model

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

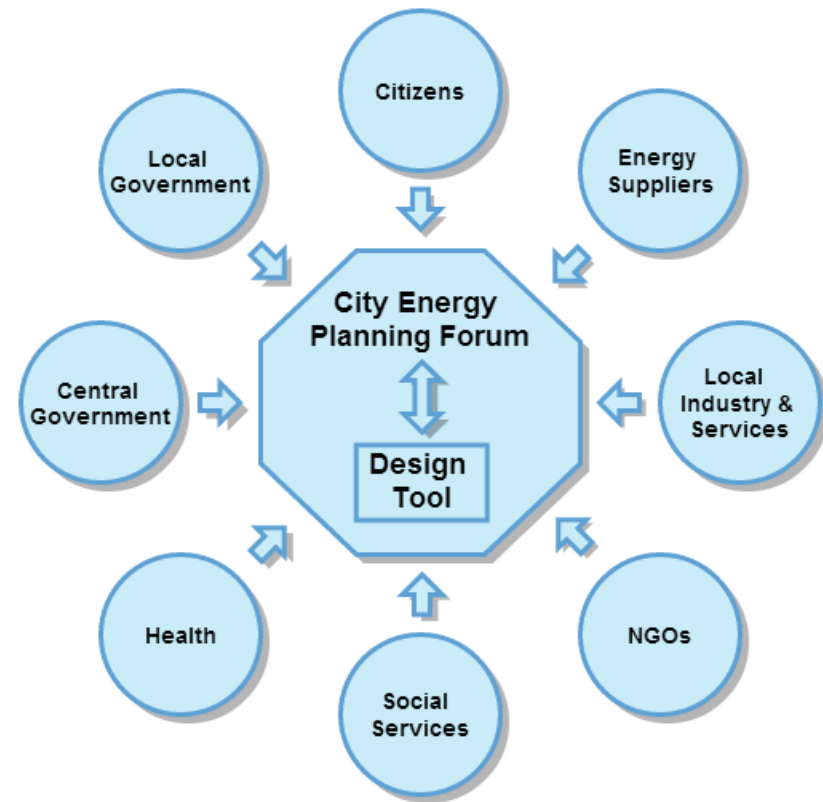
Aid planning and implementation by stakeholders using data and modelling design tools. Applicable to any city.

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

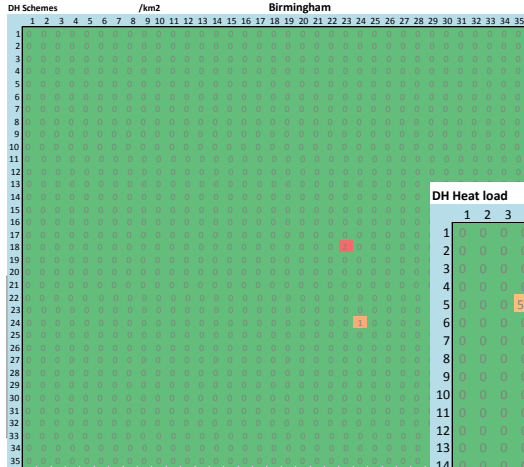
Heat load

Population (res)		Birmingham																																							
k /km2																																									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35					
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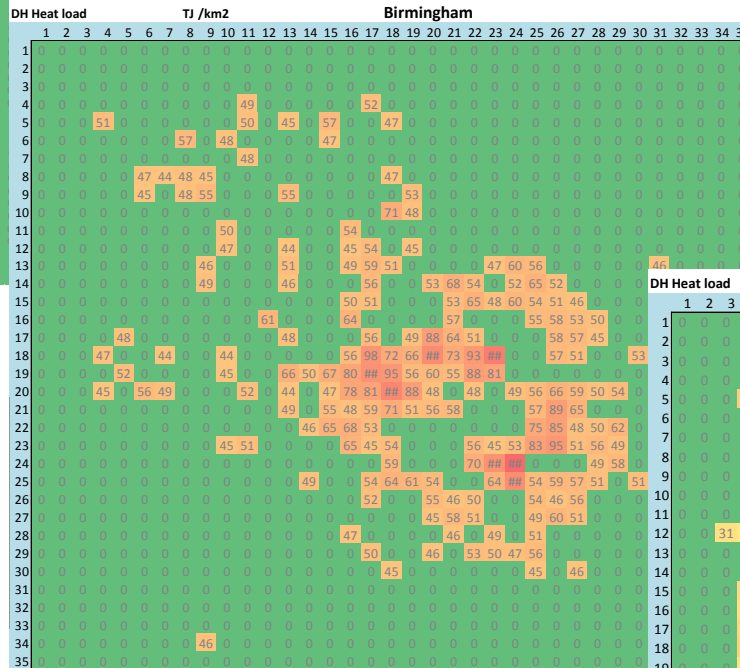
Heat load total		Birmingham																																					
TJ /km2																																							
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2015

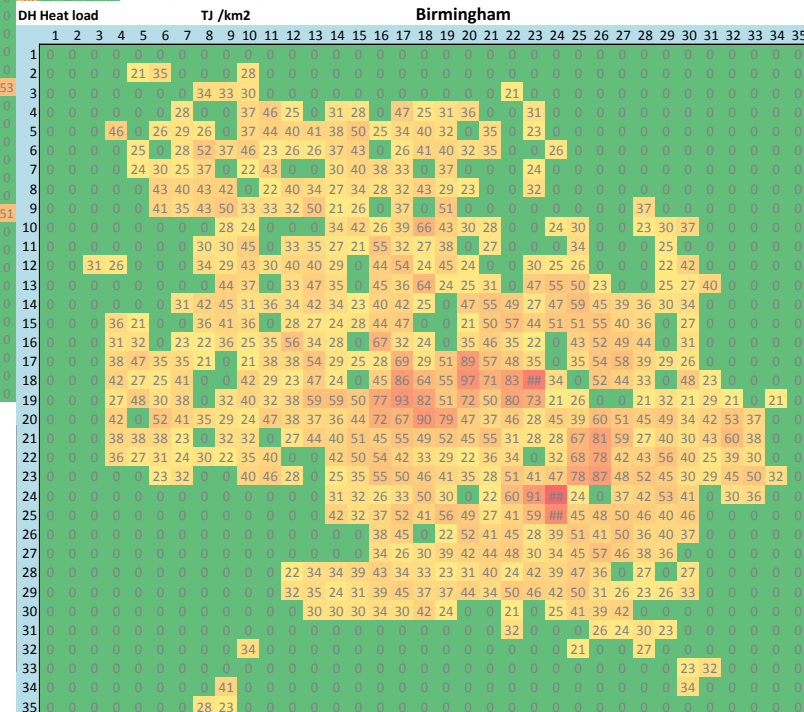
City district heating with heat pumps and CHP (illustration)



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
Pipe			£/m	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
		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	1423	7	7	11	4	15	11	
	Boiler	M£	232	226	8	8	10	4	12	9	

Pipe length	km	5278	5118	20	20	30	30	30	30	30
Storage	MWh	139732	#####	431	429	707	260	981	662	
CHP	MW	2911	2839	9	9	15	5	20	14	

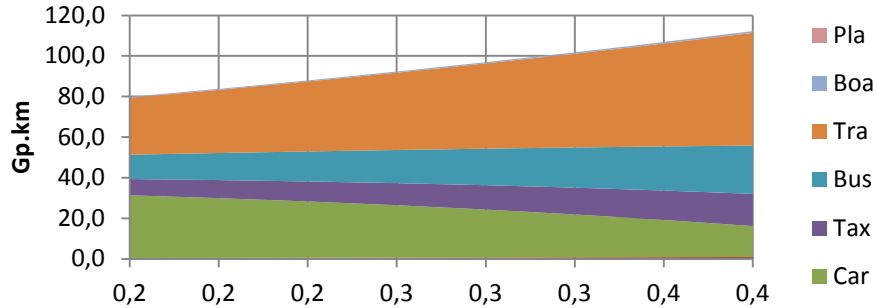


City district heating with heat pumps and CHP (illustration)

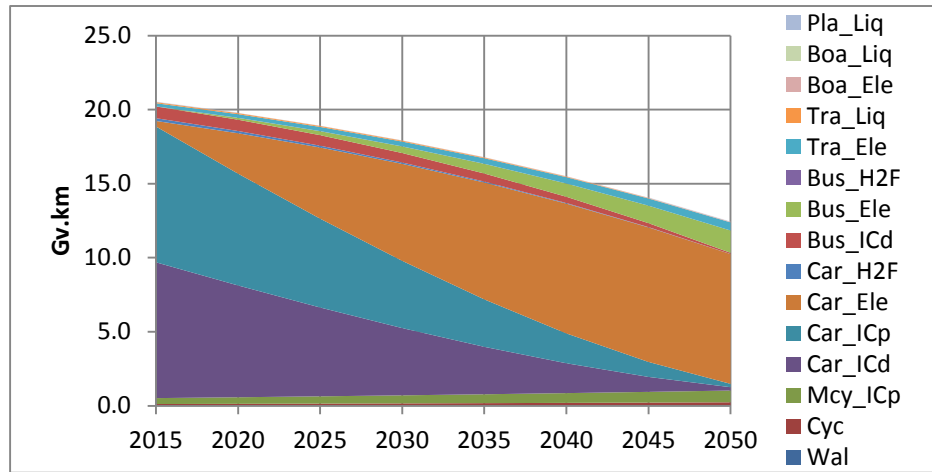
	total required	TJ		23757	23218	65	64	108	39	161	102
	Output	CHP	TJ	10691	10448	29	29	49	17	73	46
		Heat pump	TJ	10691	10448	29	29	49	17	73	46
		Boiler	TJ	2376	2322	6	6	11	4	16	10
	Fuel in	CHP	TJ	23757	23218	65	64	108	39	161	102
		Heat pump	TJ	3564	3483	10	10	16	6	24	15
		Boiler	TJ	2795	2732	8	8	13	5	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
		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)

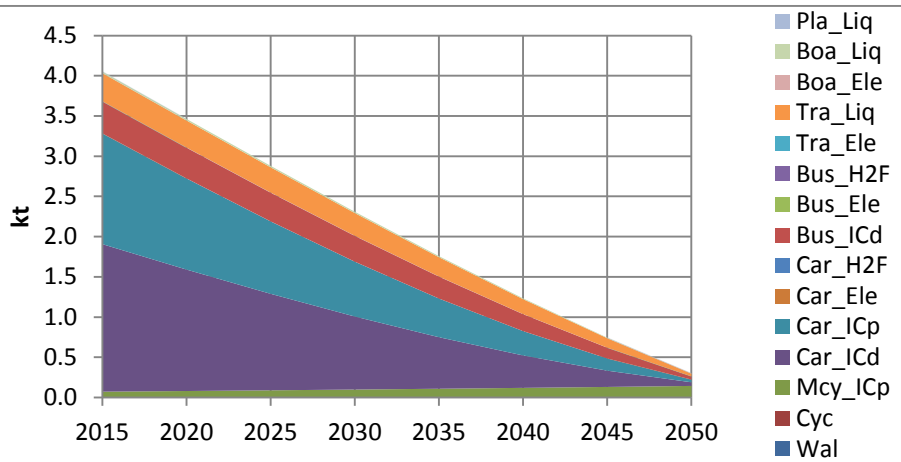
Passenger demand and mode



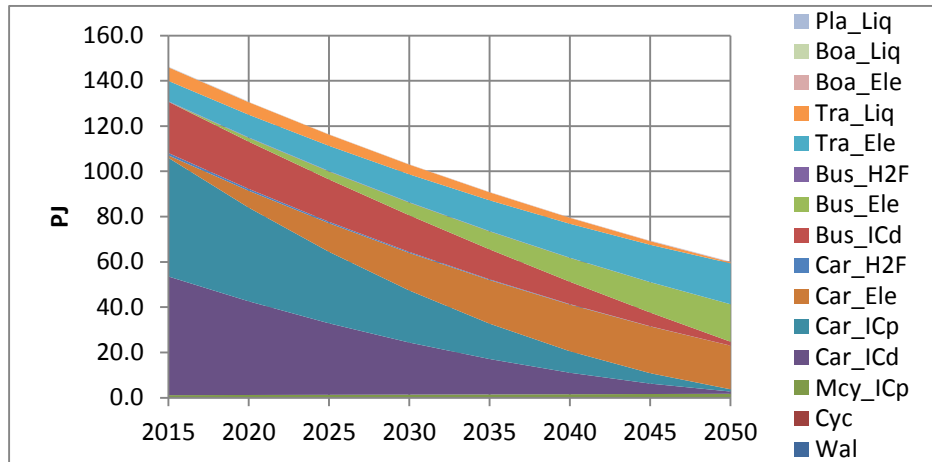
Vehicle distance



NOx emission



Vehicle energy



Thank you for listening.

Questions?