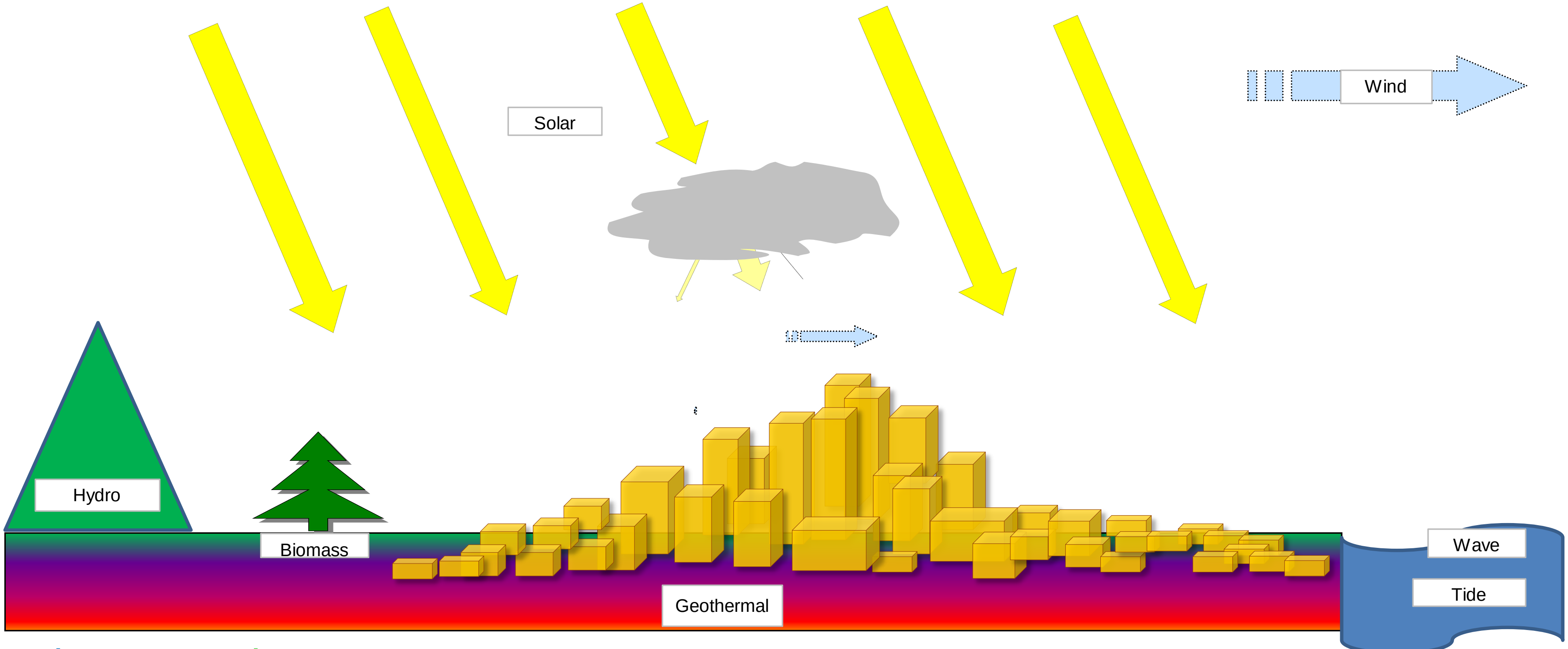
Society Energy Environment and time

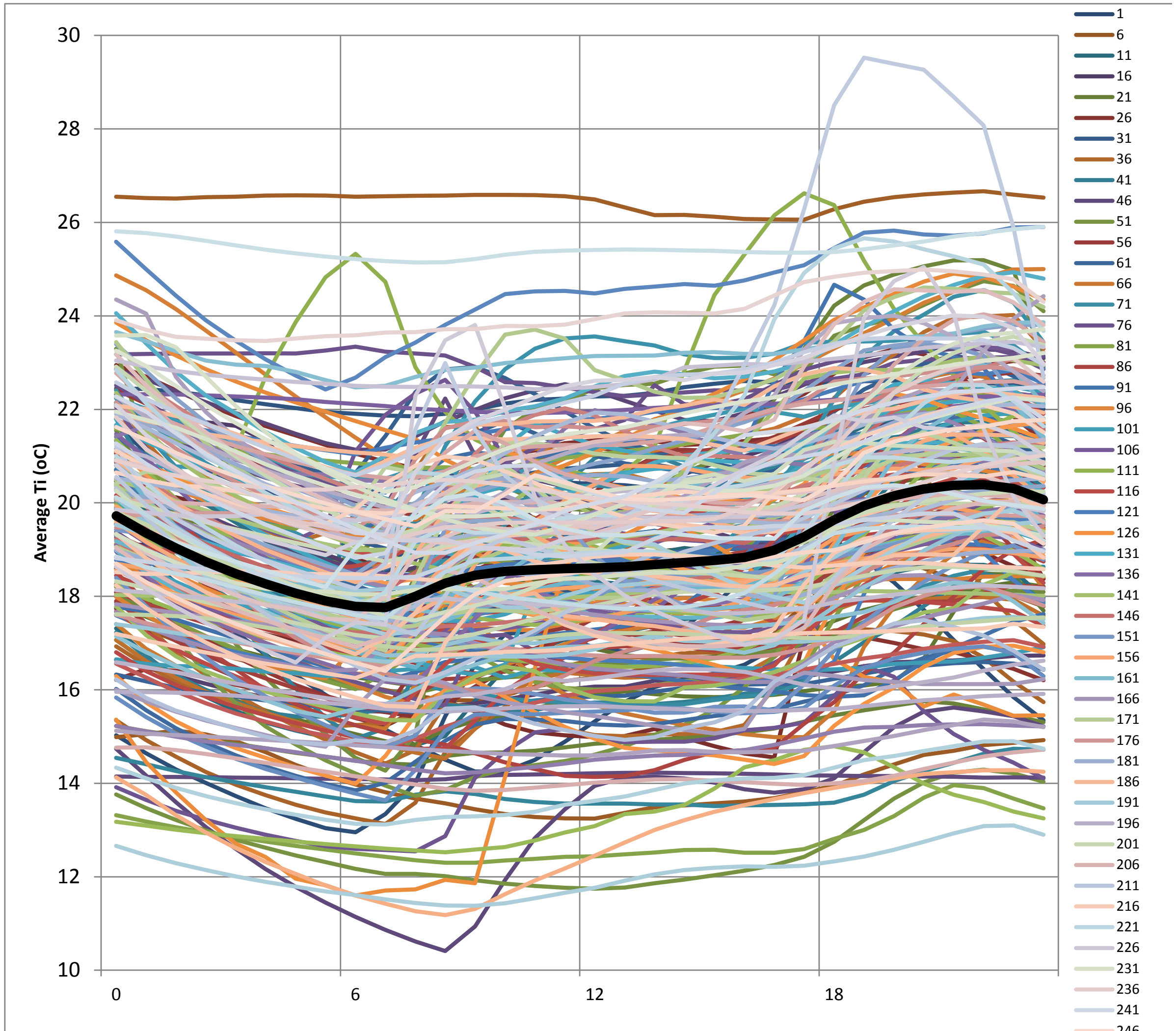
Mark Barrett



People's use of time, space and energy

- **People's behaviour privately <u>and</u> in public or private bodies is fundamental**
- **People's activities in time and space depend (somehow) on many things**
  - evolved human physiology and psychology, age, gender, 'culture', occupation, household, health, wealth, location, infrastructure, energy prices, weather, holidays, etc.
- **People's service needs vary in time (hours to years) and space**
- **Richer people use almost all services in building and transport interiors**
- **People use services in groups much of the time in buildings and transport.**
- **Service demands, with end use technologies (including sweaters) and controls, cause energy demands**
- **Primary energy supply system options depend on energy demands**
- **Temporal energy flows arise from <u>all</u> services for people and their machines, the infrastructure, and the <u>whole</u> energy system including <u>control</u>: all operating within a <u>meteorology</u> affecting demand and renewables.**

Jackson Pollock lives?



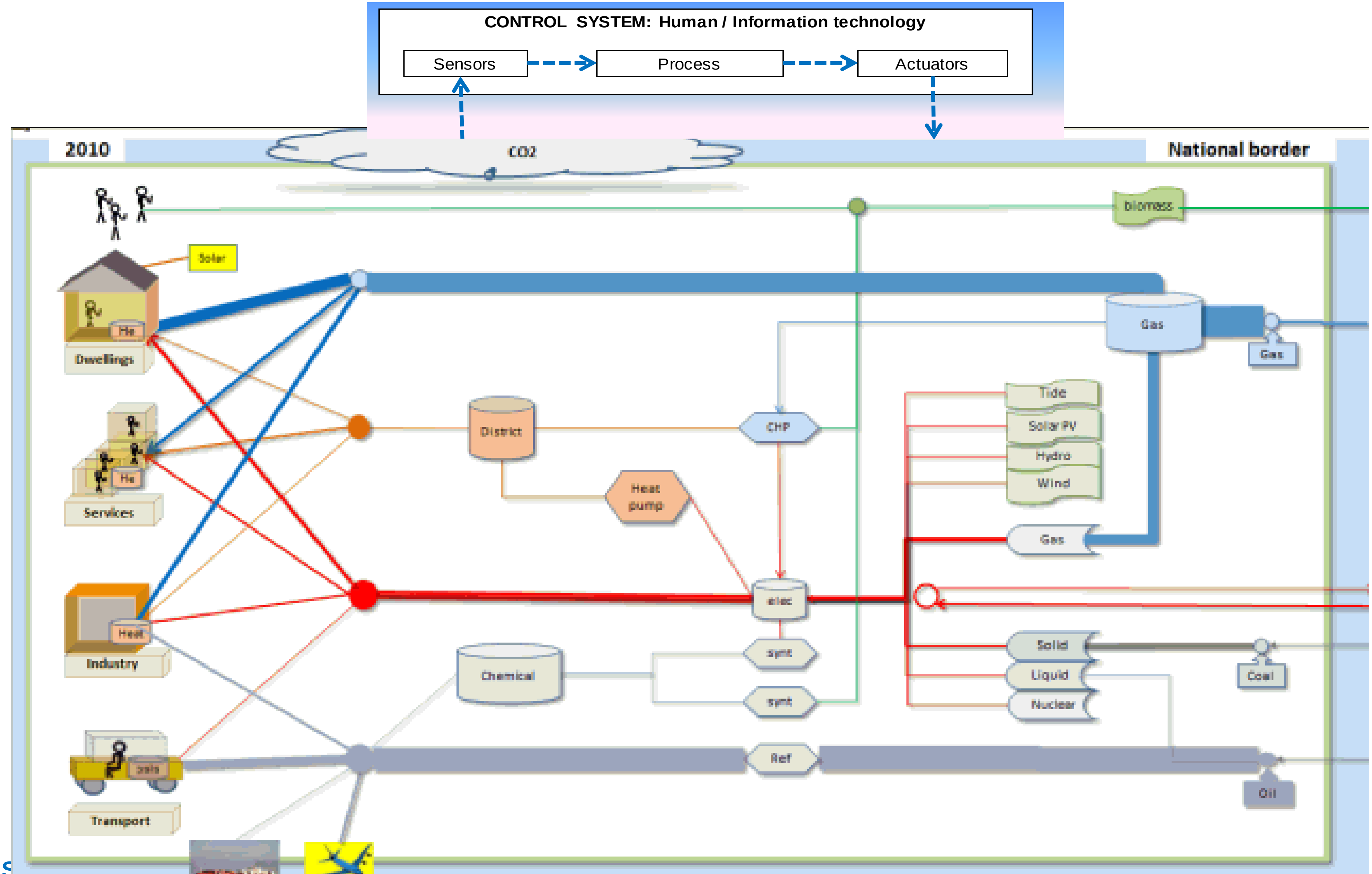
Sample temperature data from 248 houses resulting from human-technology complexes.

What does such a variation mean for services, energy and environment?

Can we understand and model the complexes now, and as people and technologies might change in the future?

How precise do we need to be for policy and planning for an uncertain future?
Where are the elephants?

People are what social energy systems are for

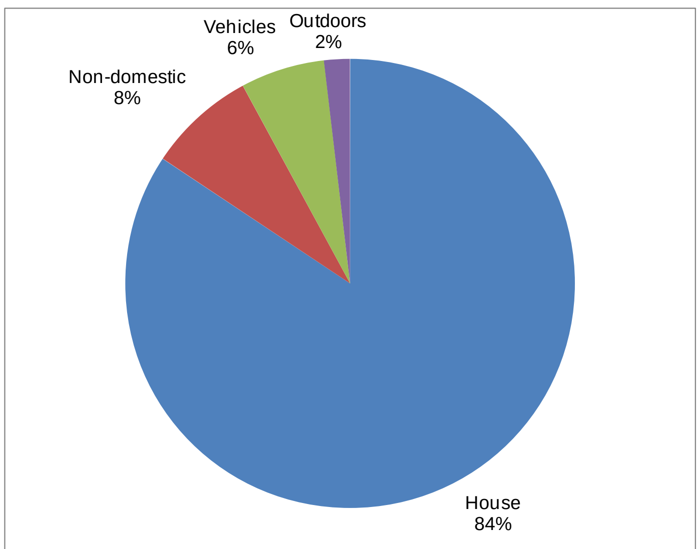


UK Personal time use : by space and activity

By space

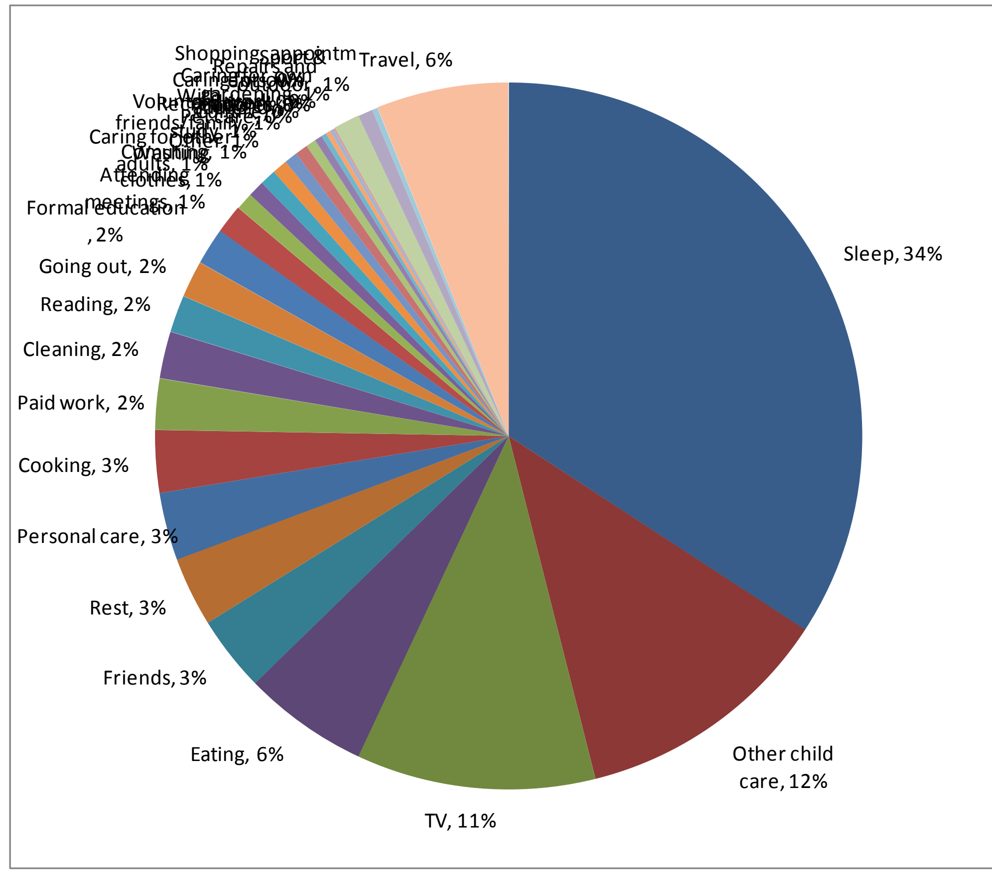
Nearly as much time in vehicles as non-domestic buildings.

Vehicle space heat load larger than non-domestic? Insulate cars?



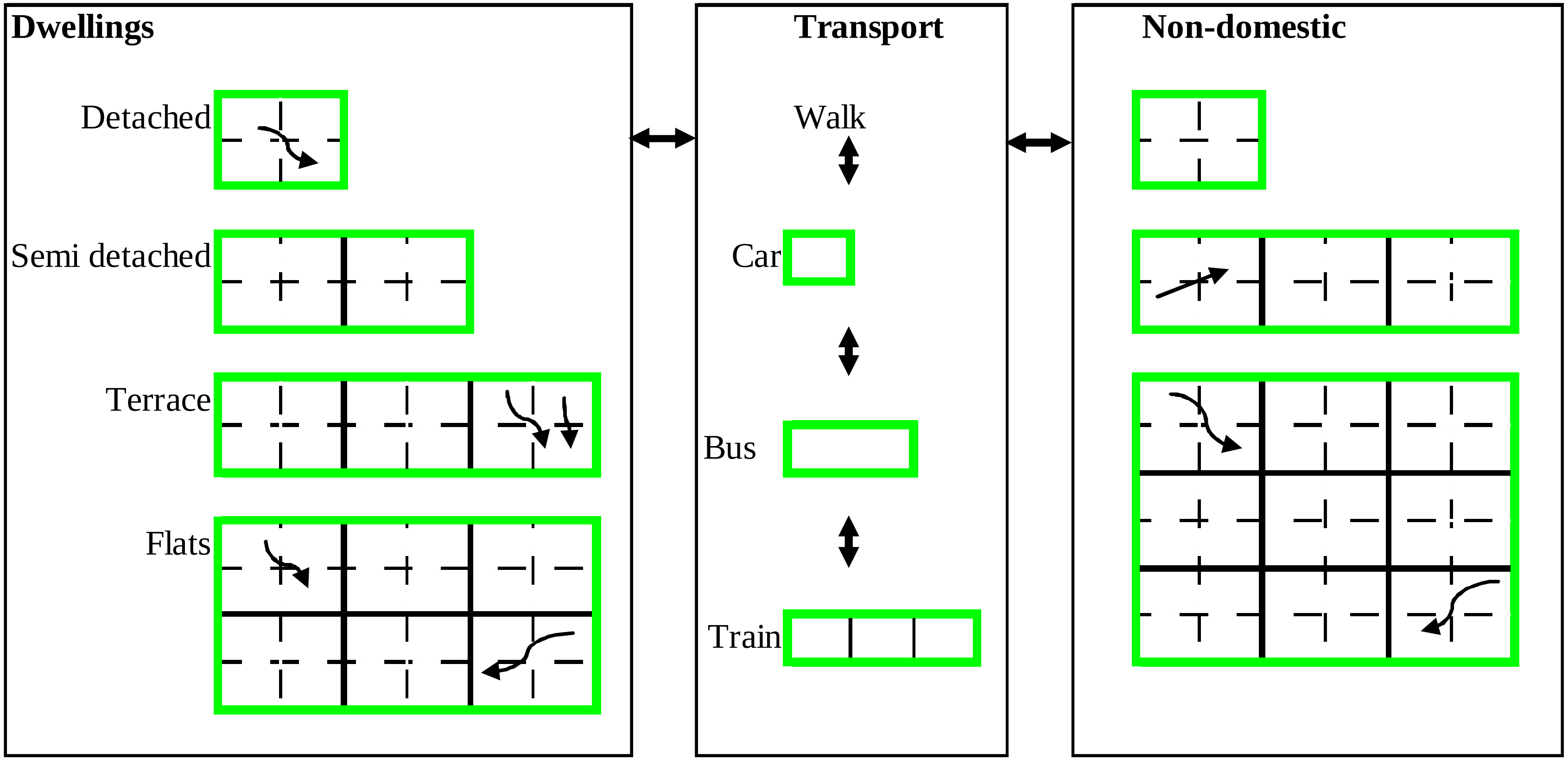
By activity

Insulate/heat beds and sofas? We used to do this!



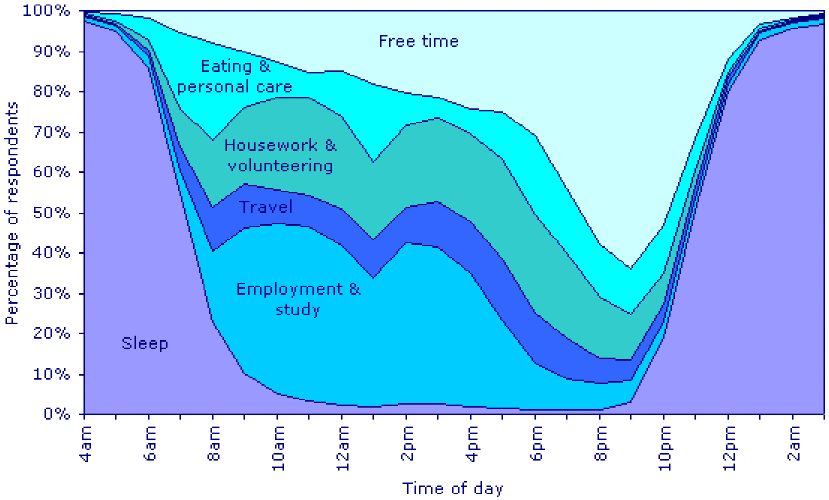
Homo multicellulus – a life in boxes

- ~98% of (wealthy) human lifetime spent in stationary or mobile boxes
- Most services provided there: food, water, air, warmth, light, waste etc.

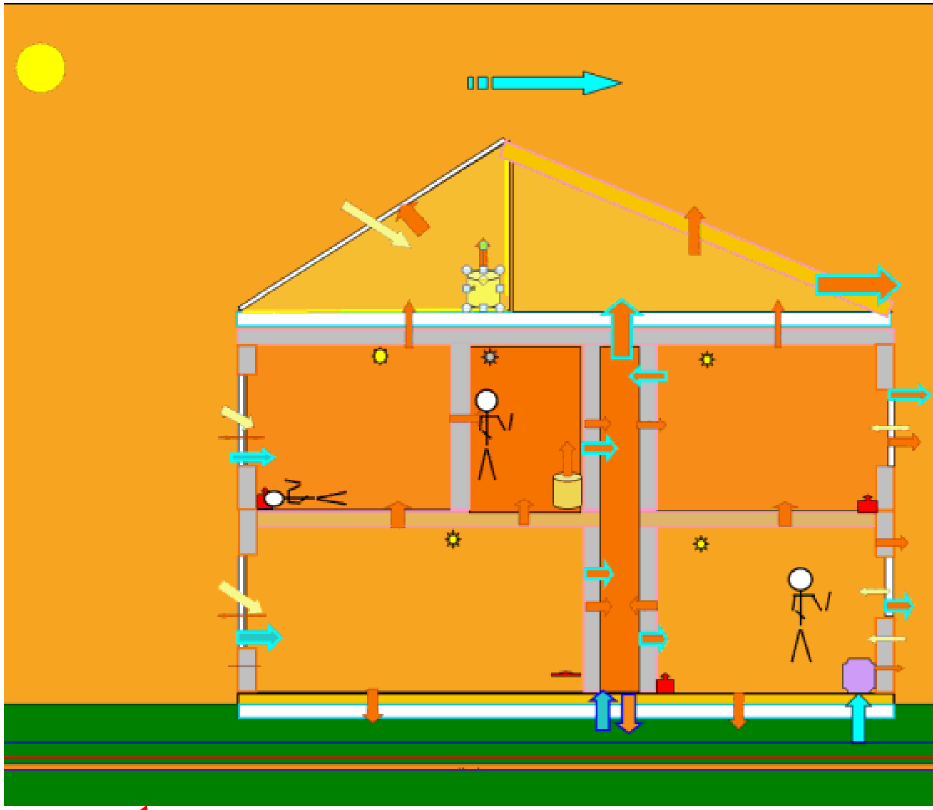


DynEMo Temporal drivers

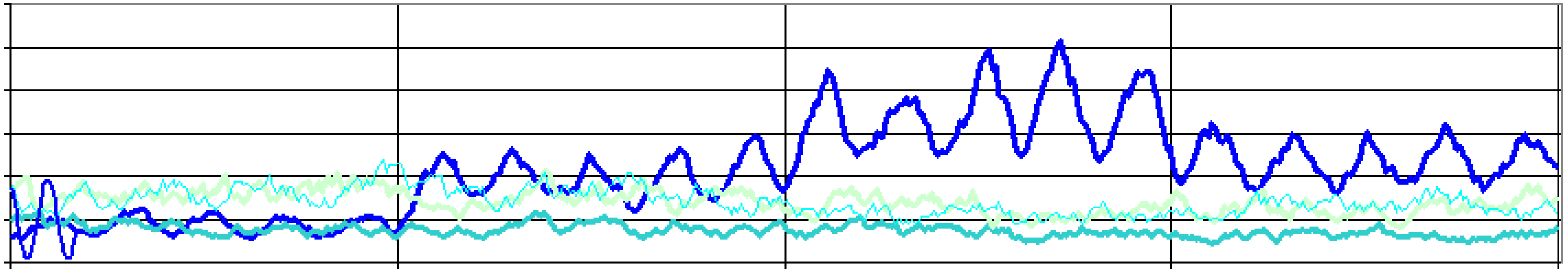
Human use of time – UK
Quite invariable –
a diurnal mammal!



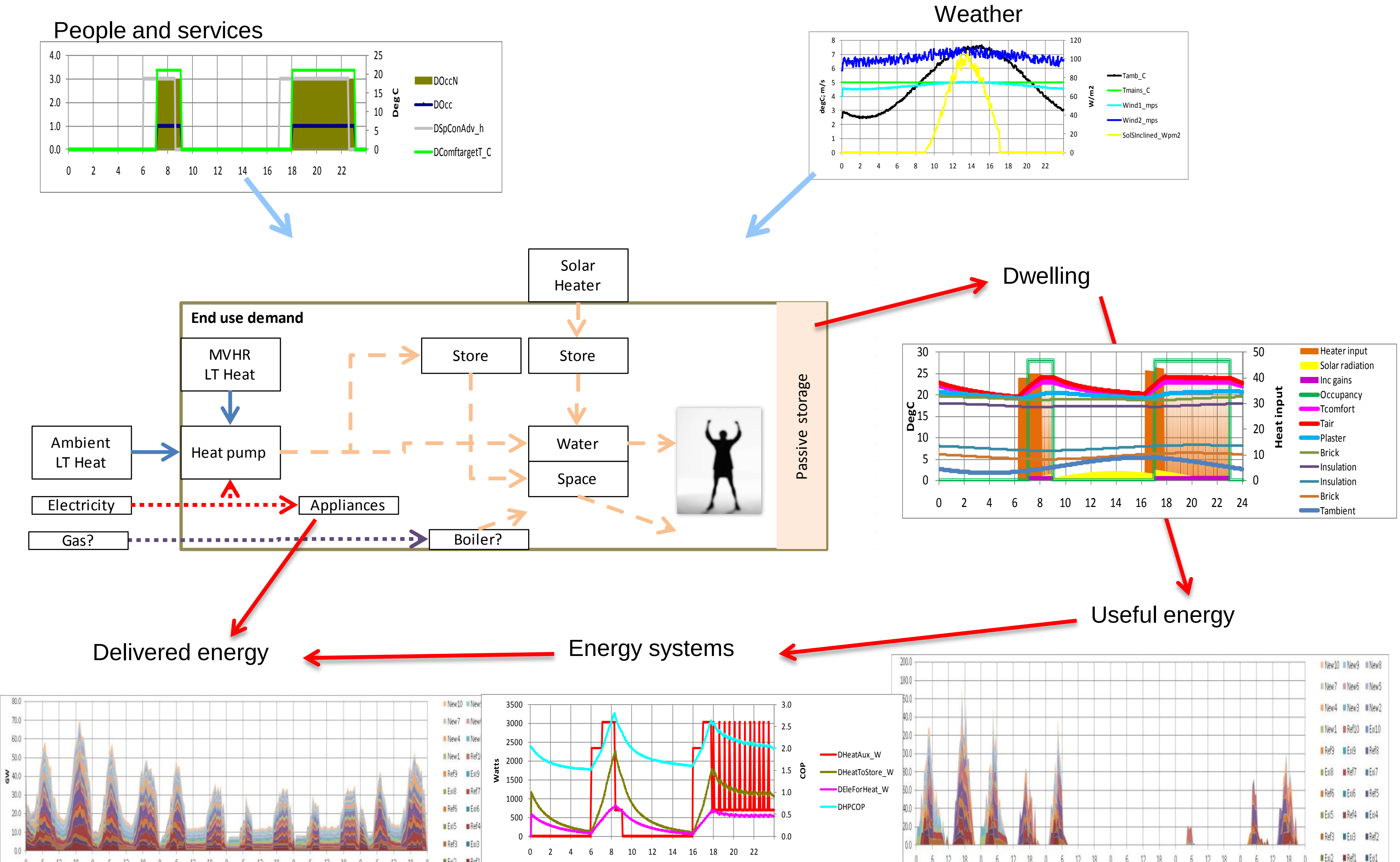
Infrastructure



Weather and Renewables



People-dwelling combination calculation process



PEOPLE DWELLING COMBINATIONS / SEGMENTS – existing and refurbished

Inputs **Output results**

People Building Energy Cost

AVERAGE				2.5		26	4	188	61			145	180
TOTAL			25.2	62.8		655	106	4747	1541			3652	4534
INPUTS													
			People			Services		Building		Supply		Building	
Country	Region	Class	Pop_M	HHSize	DOccPatt_N	DHW_lpPpd	Dapp_GJpP	DFabLoss_WpC	DVentLoss_WpC	DSolHWArea_m2	HeatFuel	EnvArea_m2	Volume_m3
GBR	GBR50	E1	0.9	1.0	1	26	4	169	56	0	gb	130	165
GBR	GBR50	R1	0.0	1.0	1	21	3	101	45	0	dh	130	165
GBR	GBR50	E2	0.9	1.0	2	26	4	169	56	0	eop	130	165
GBR	GBR50	R2	0.0	1.0	2	21	3	101	45	0	dh	130	165
GBR	GBR50	E3	0.9	1.0	3	26	4	169	56	0	gb	130	165
GBR	GBR50	R3	0.0	1.0	3	21	3	101	45	4	dh	130	165
GBR	GBR50	E4	0.9	1.0	4	26	4	169	56	0	lb	130	165
GBR	GBR50	R4	0.0	1.0	4	21	3	101	45	0	gb	130	165
GBR	GBR50	E5	0.9	1.0	5	26	4	169	56	0	gb	130	165
GBR	GBR50	R5	0.0	1.0	5	21	3	101	45	0	hp	130	165
GBR	GBR50	E6	0.9	1.0	6	26	4	169	56	0	gb	130	165
GBR	GBR50	R6	0.0	1.0	6	21	3	101	45	0	dh	130	165
GBR	GBR50	E7	0.9	2.0	1	26	4	182	60	0	gb	140	175
GBR	GBR50	R7	0.0	2.0	1	21	3	109	48	0	dh	140	175
GBR	GBR50	E8	0.9	2.0	2	26	4	182	60	0	gb	140	175
GBR	GBR50	R8	0.0	2.0	2	21	3	109	48	0	hp	140	175
GBR	GBR50	E9	1.3	2.0	3	26	4	182	60	0	gb	140	175
GBR	GBR50	R9	0.0	2.0	3	21	3	109	48	0	dh	140	175
GBR	GBR50	E10	1.3	2.0	4	26	4	182	60	0	gb	140	175
GBR	GBR50	R10	0.0	2.0	4	21	3	109	48	4	hp	140	175
GBR	GBR50	E11	1.3	2.0	2	26	4	182	60	1	gb	140	175
GBR	GBR50	R11	0.0	2.0	2	21	3	109	48	0	hp	140	175

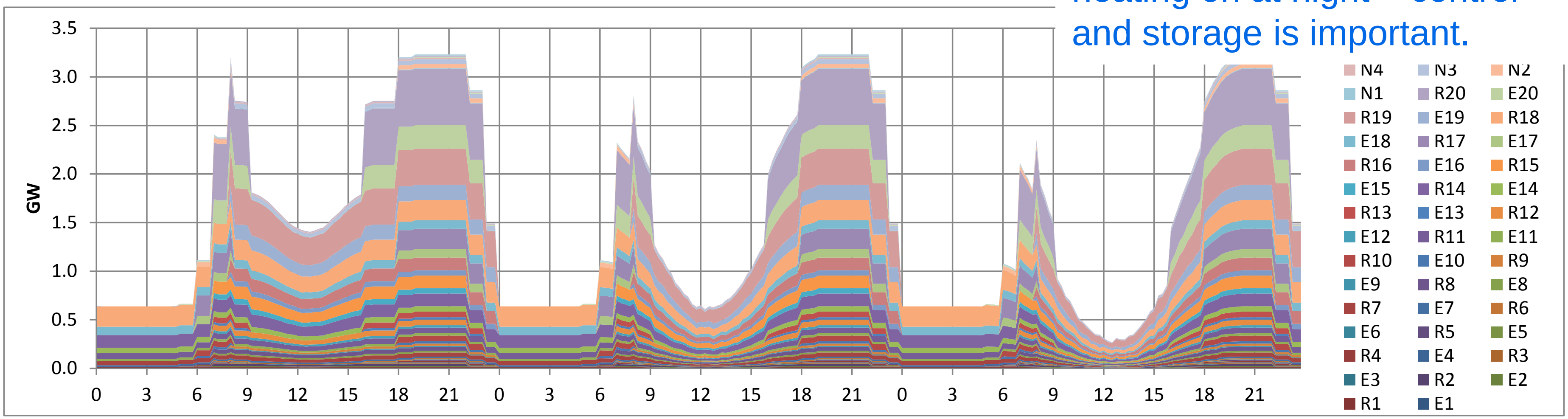
Load curves for Person-Dwelling Combinations

NB: this is for the UK. French people have longer (and many say better) lunches and seem to keep electric heating on at night – control and storage is important.

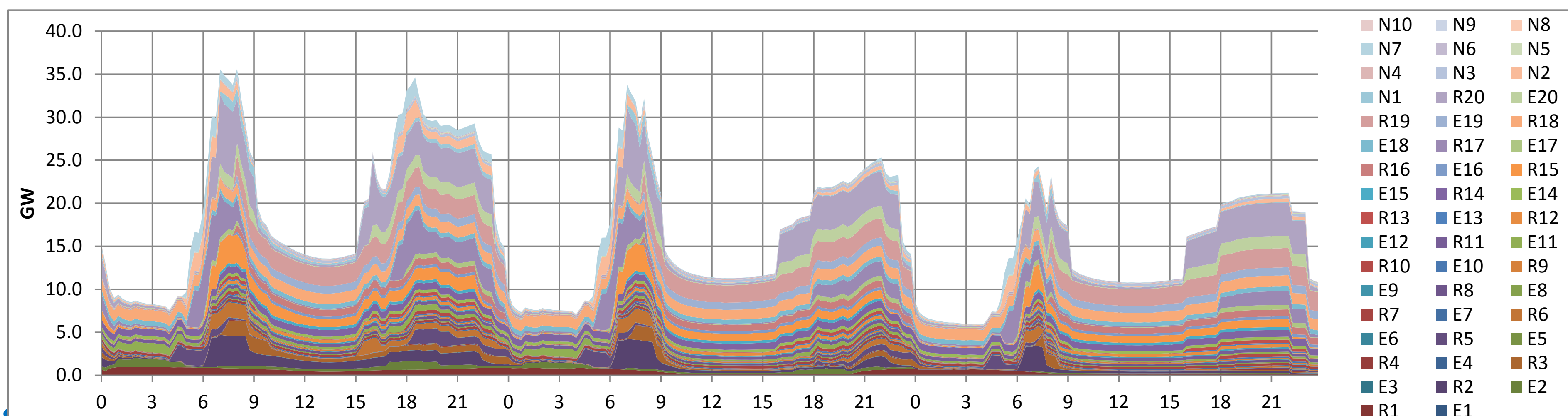
GBR Demolish 3% Refurb 75%

GBR:Yr 2050 3 days: 1 days/month; months 1,4,7 [Calc at 15 min interval GW

Light

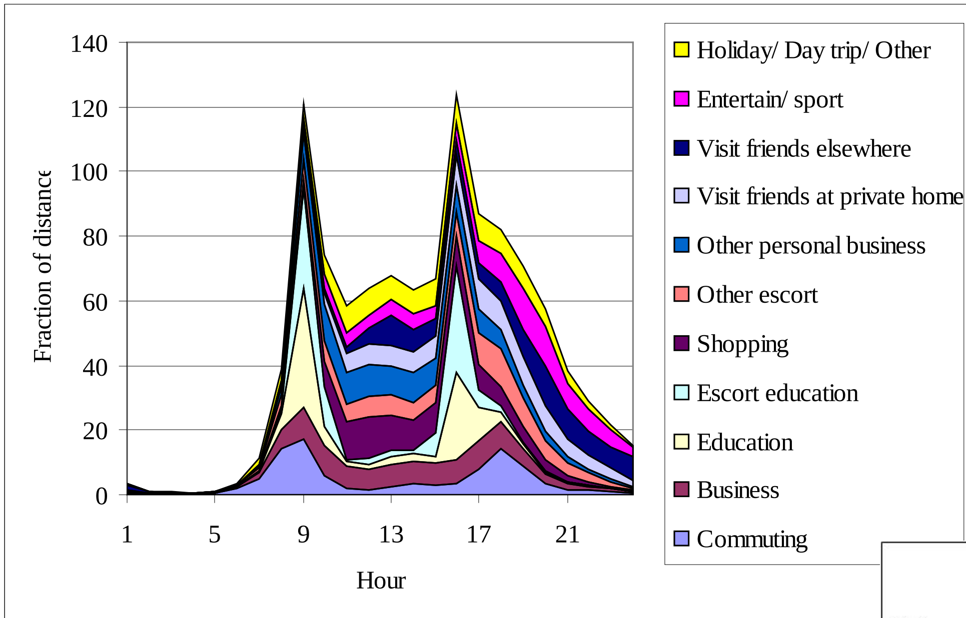


Delivered electricity



Travel patterns

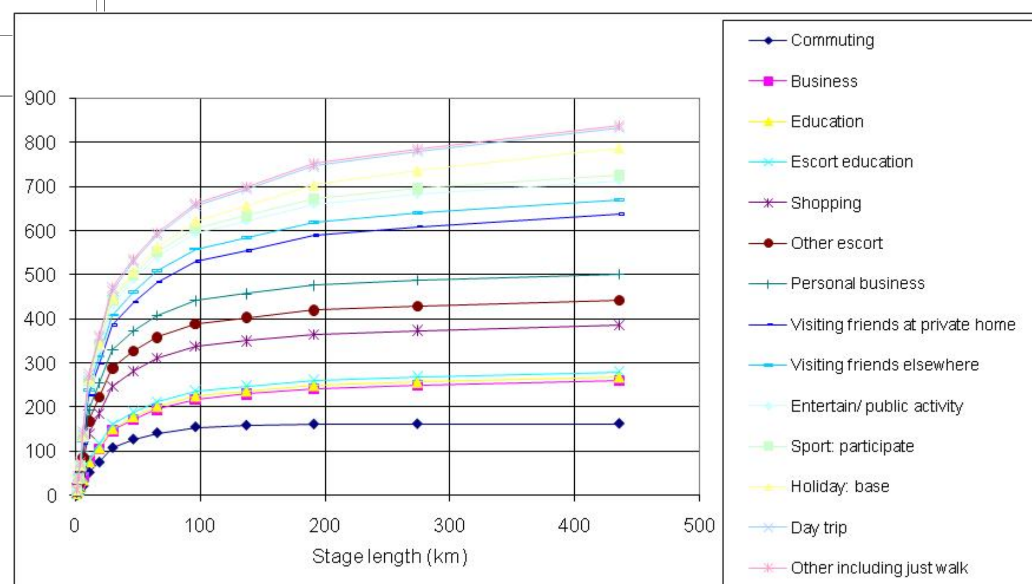
Time



The temporal and spatial pattern of travel influences transport options.

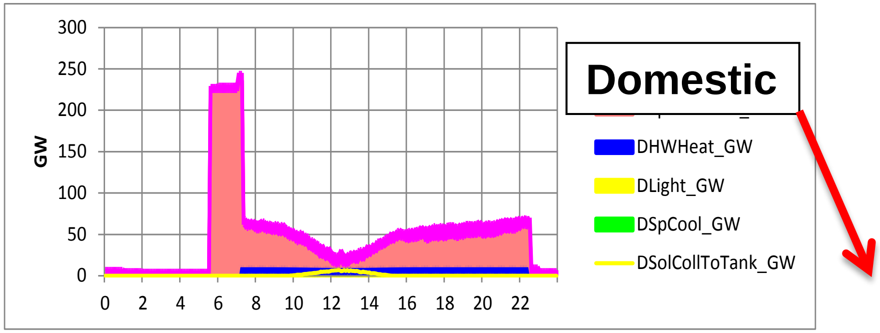
e.g. electricity only cars can generally be charged when other demands are low, and service around 85% of trips (100% if hybrid).

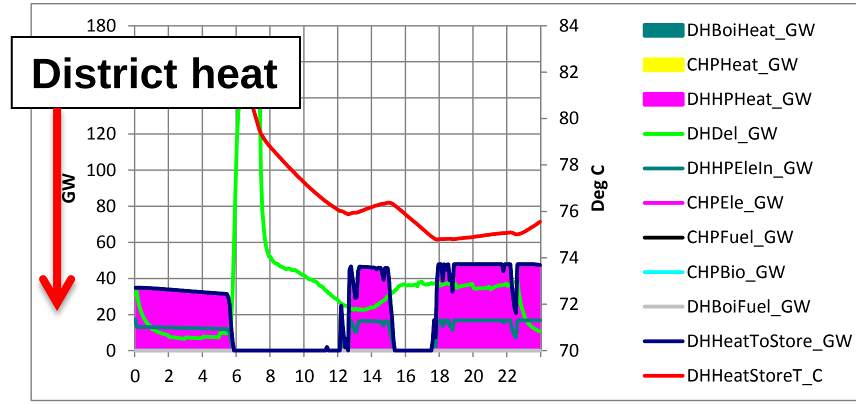
Trip distance

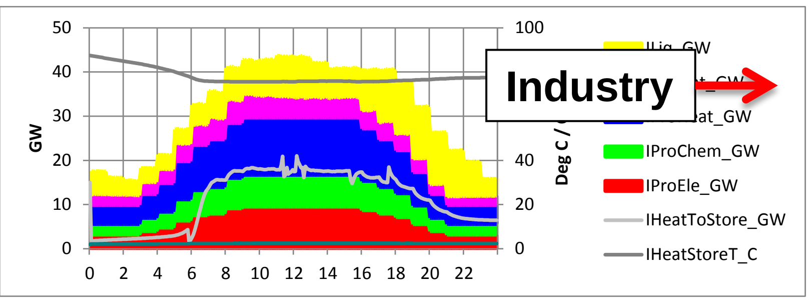


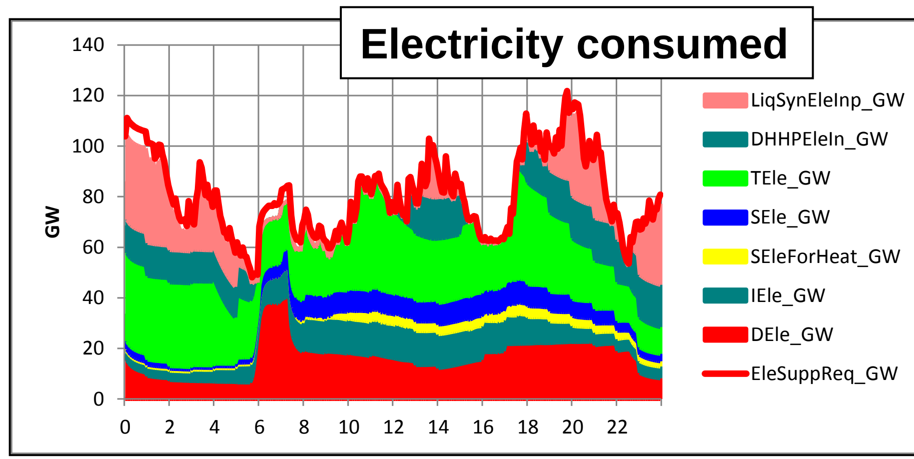
From National Travel Survey: 2005/6

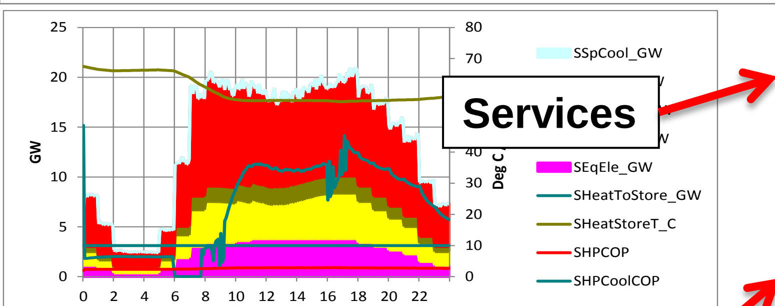
Energy consumption – DynEMo one day for month 1 ; modelled at 5 min intervals

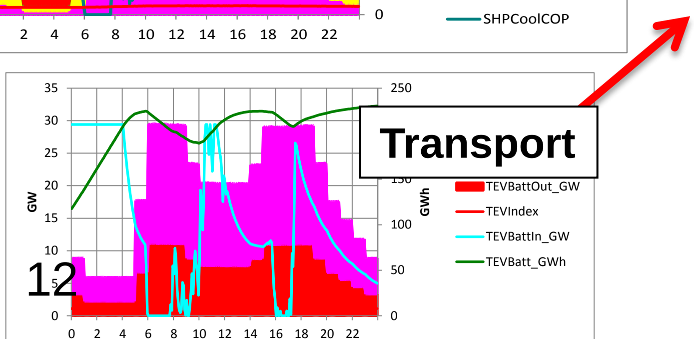


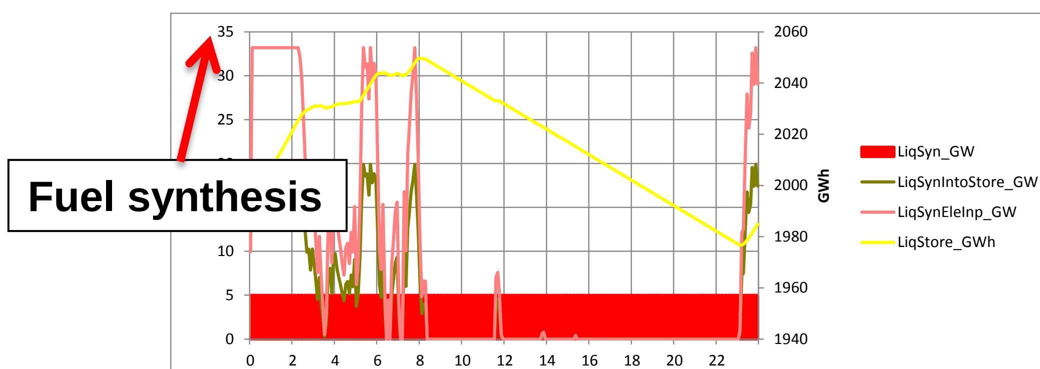






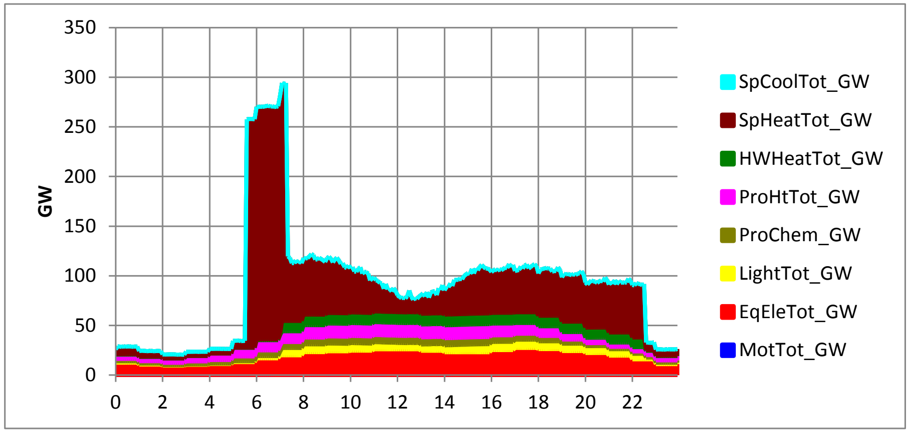




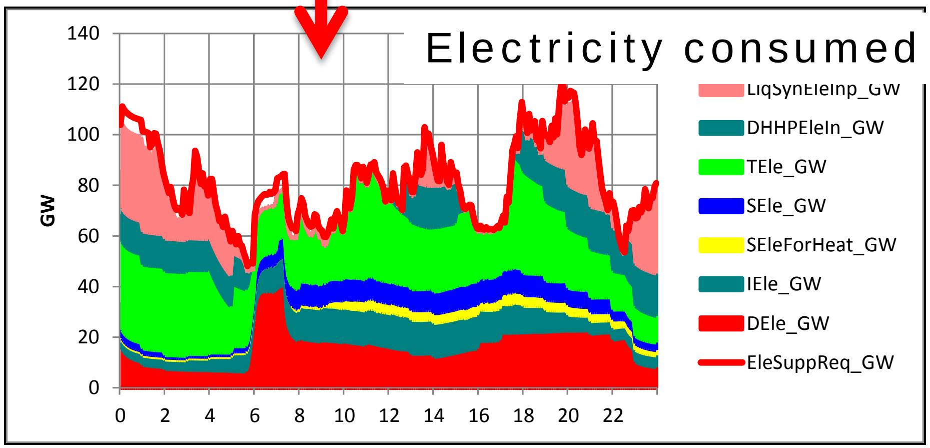


Matching demand to supply – DynEMo 1 day for months 1 ; modelled at 5 min intervals

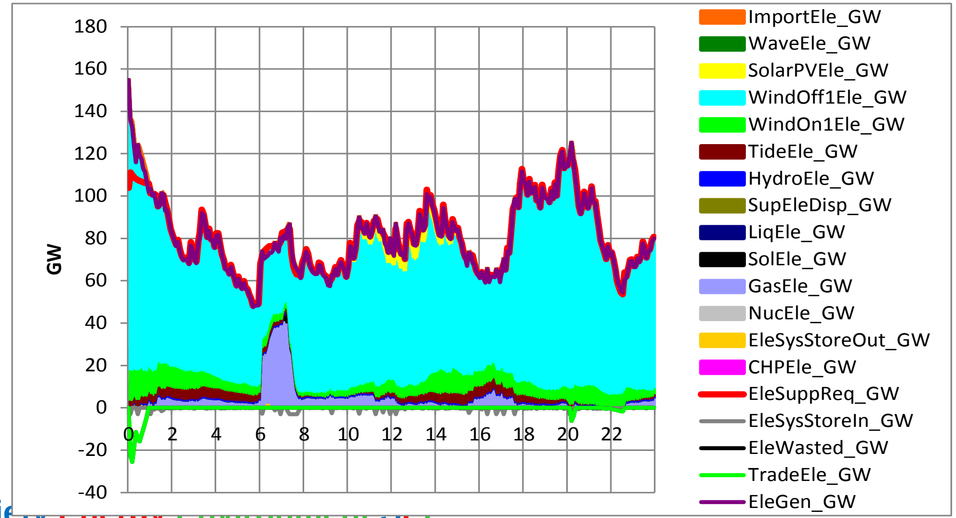
Useful energy



Electricity consumed

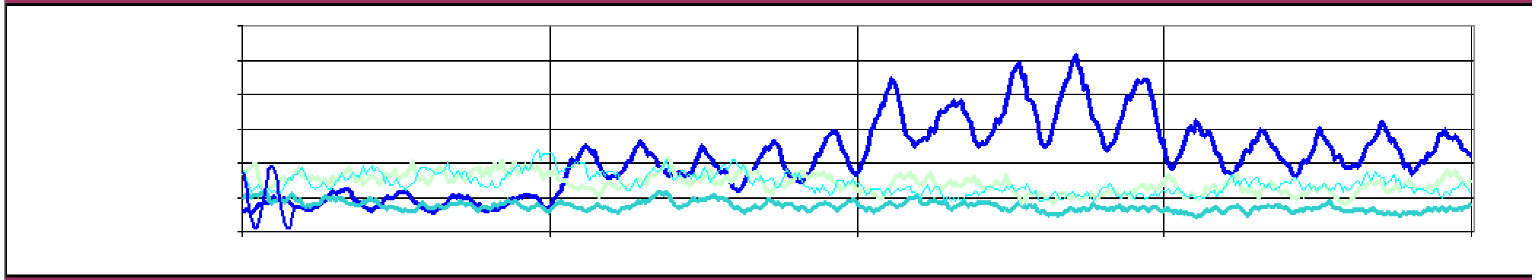


Electricity generation and trade



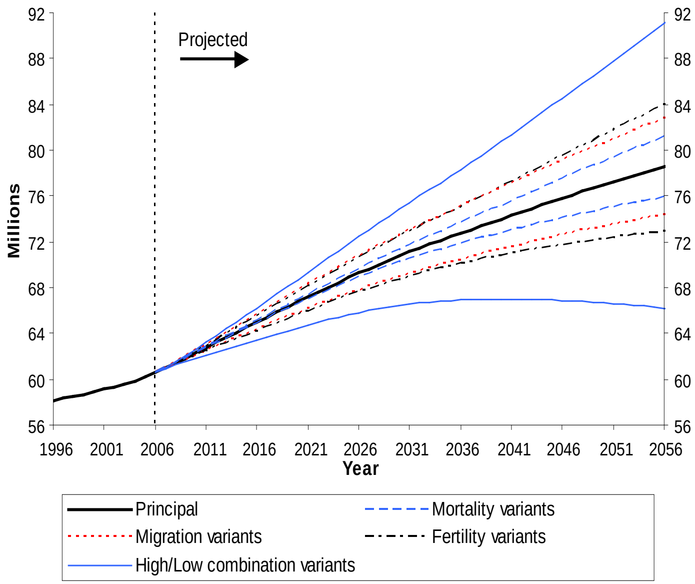
Dynamic system control – months : animated

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

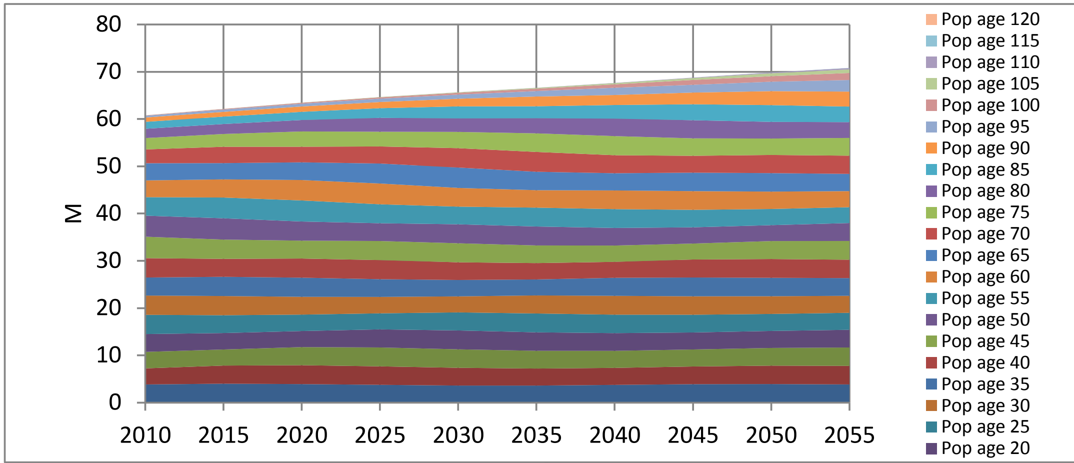


Demography, households and dwellings

Population uncertainty

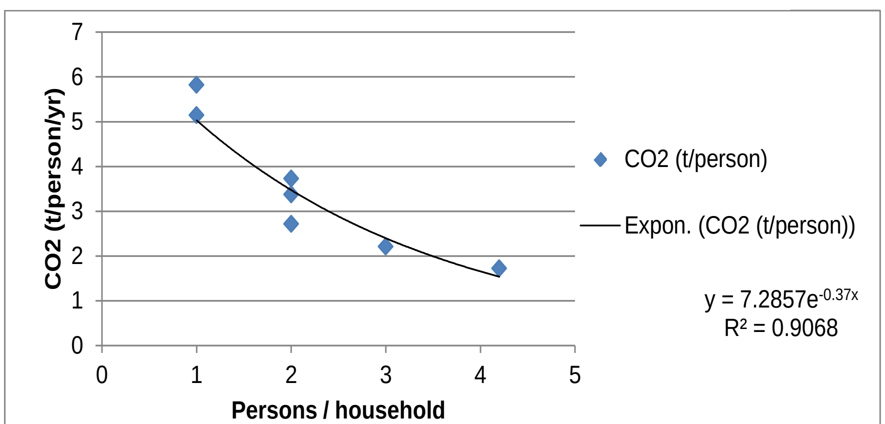


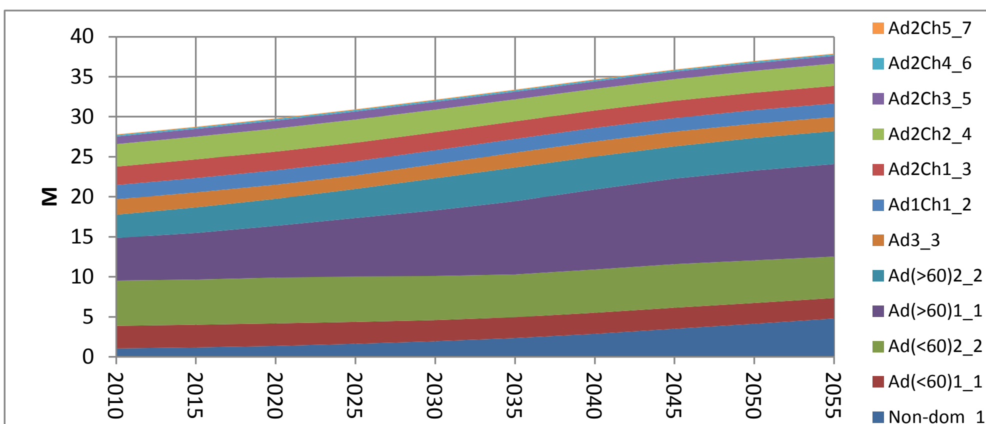
Population: ageing



More energy and carbon per person in small households

Households - smaller





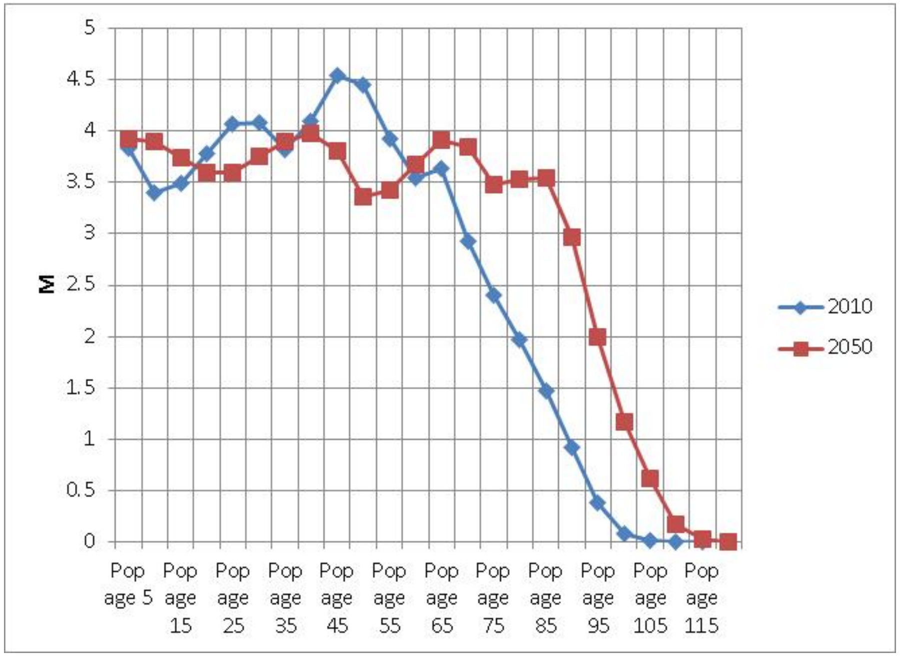
Future UK demography: population and age

Ageing population, at least in the UK…

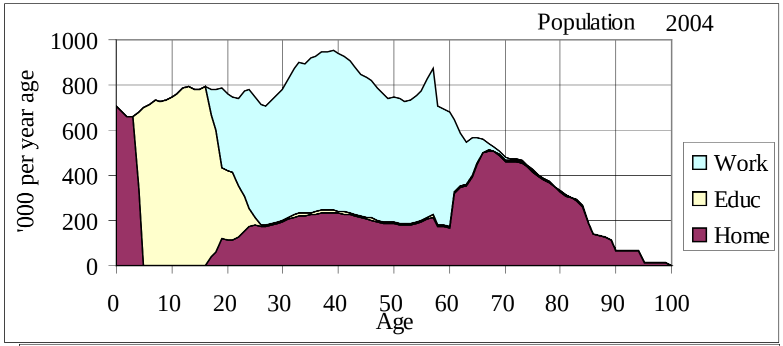
How will the activities of people of different ages change?

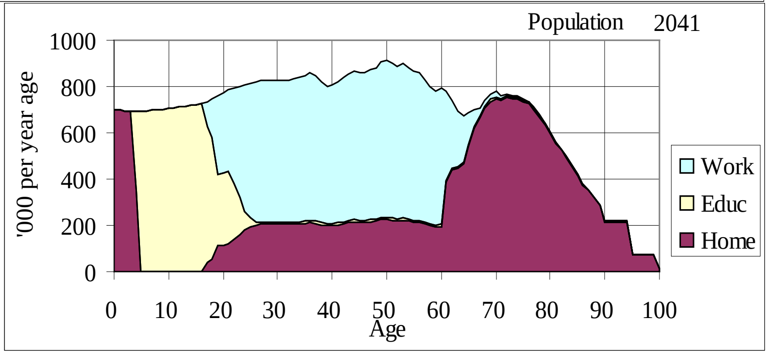
What sort of buildings and transport will we need for these activities?

Age profiles for 2010 and 2050 from model



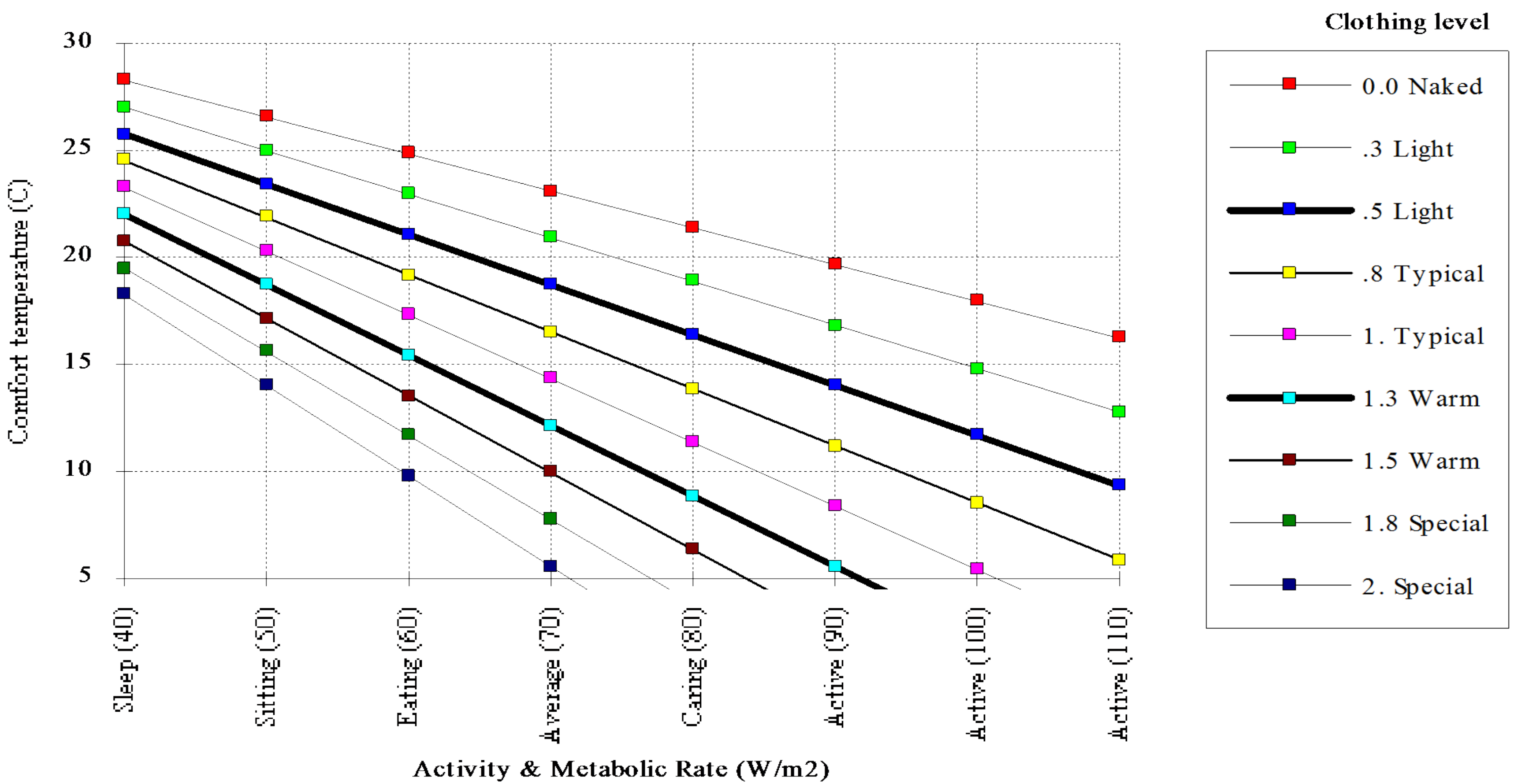
From Government Actuarial Department
(allocation to activity by Barrett)





Comfort temperature, clothing and activity

Appropriate clothing reduces energy demand and emissions. A slight improvement in clothing could reduce building temperatures. A degree reduction in average building temperature could reduce space heating needs by about 10%.

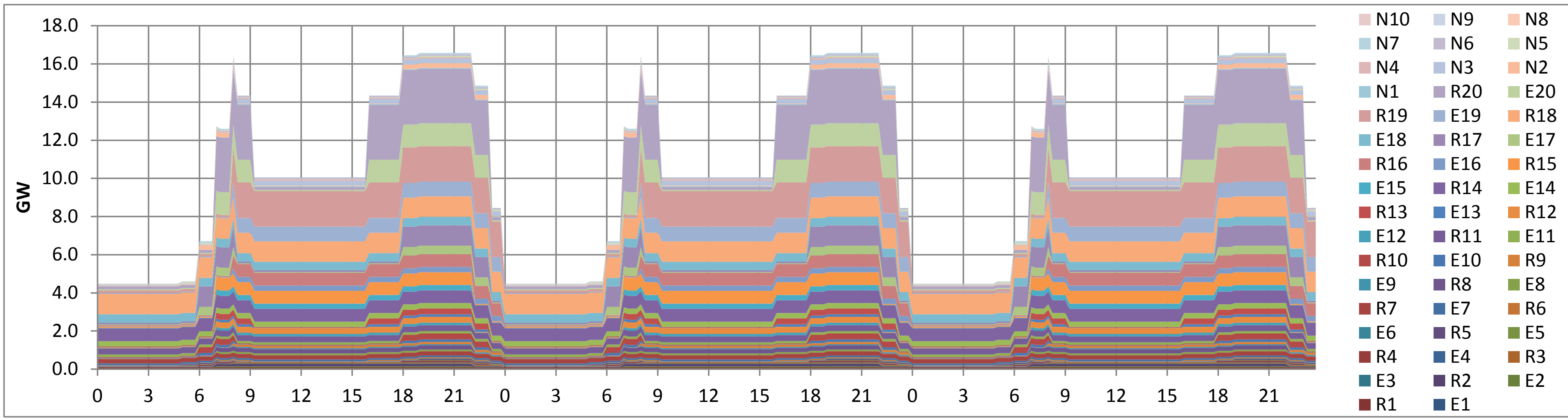


Load curves for Person-Dwelling Combinations

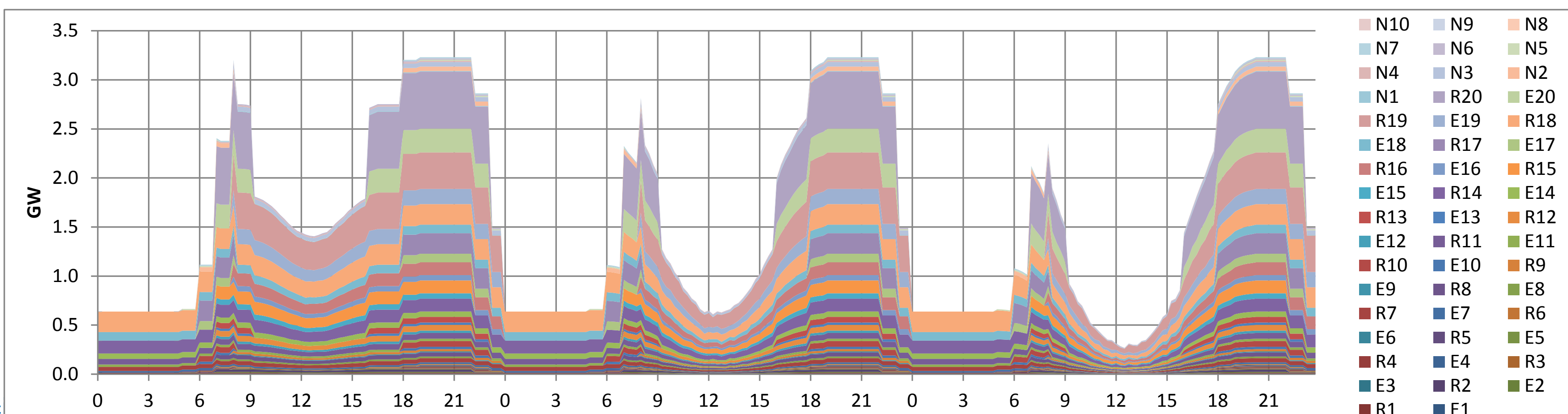
GBR Demolish 3% Refurb 75%

GBR:Yr 2050 3 days: 1 days/month; months 1,4,7 [Calc at 15 min interval GW

Appliances



Light



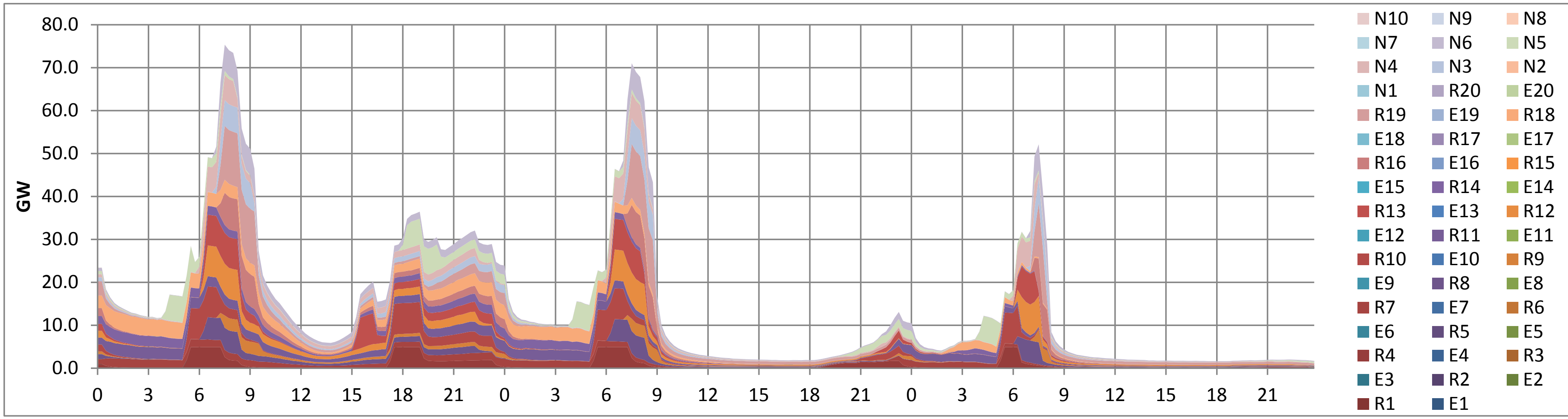
Soc

Load curves for Person-Dwelling Combinations

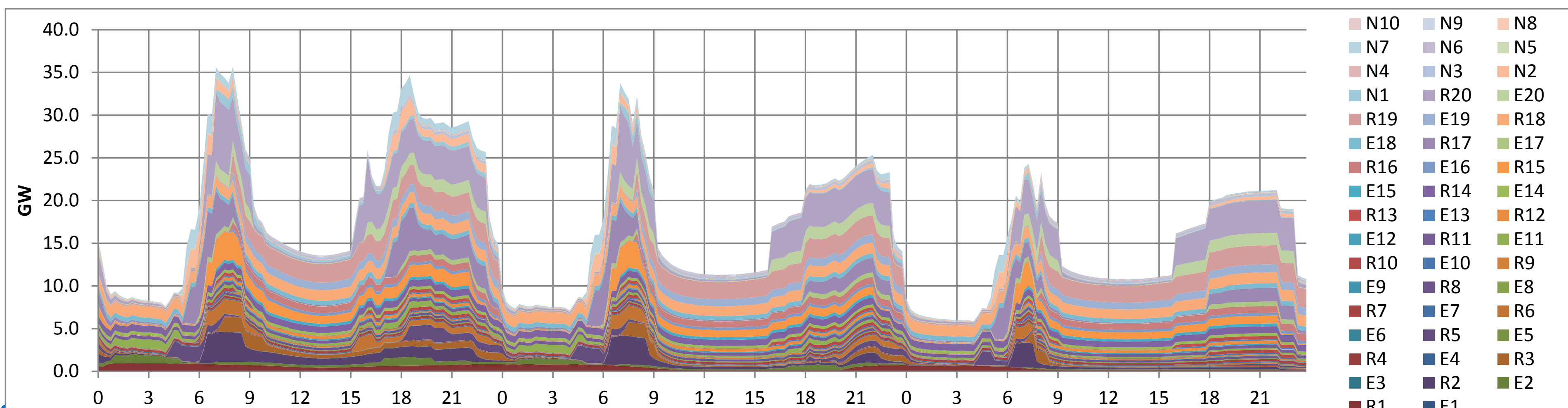
GBR Demolish 3% Refurb 75%

GBR:Yr 2050 3 days: 1 days/month; months 1,4,7 [Calc at 15 min interval GW

District heat delivered



Delivered electricity

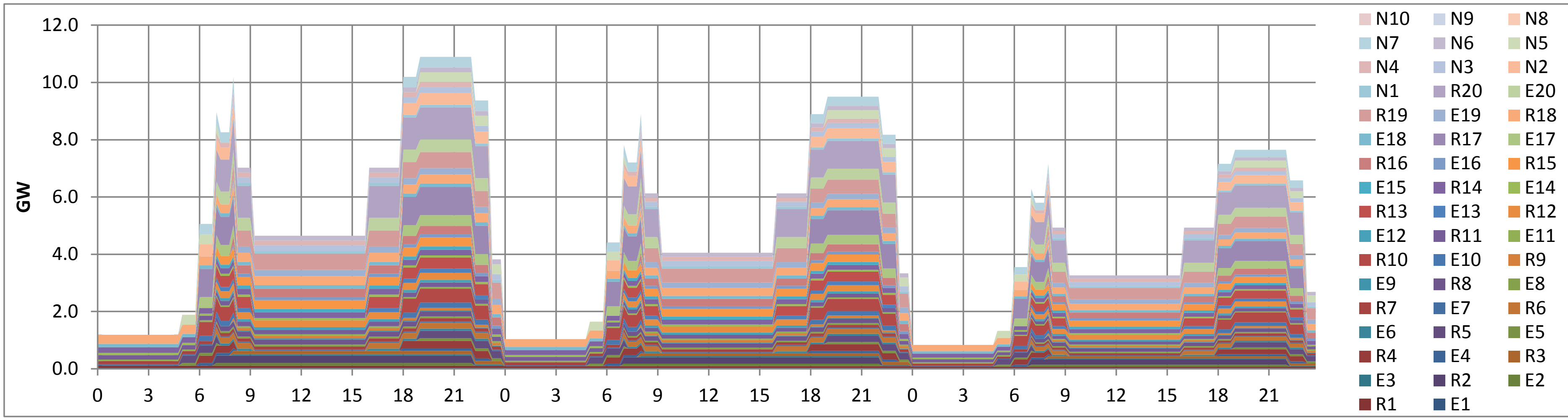


Load curves for Person-Dwelling Combinations

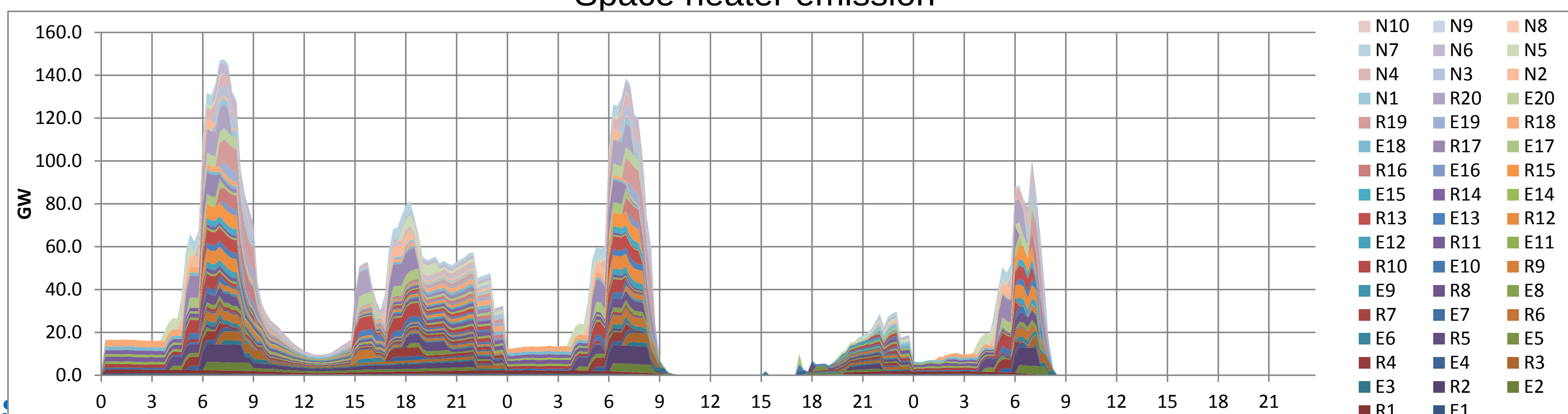
GBR Demolish 3% Refurb 75%

GBR:Yr 2050 3 days: 1 days/month; months 1,4,7 [Calc at 15 min interval GW

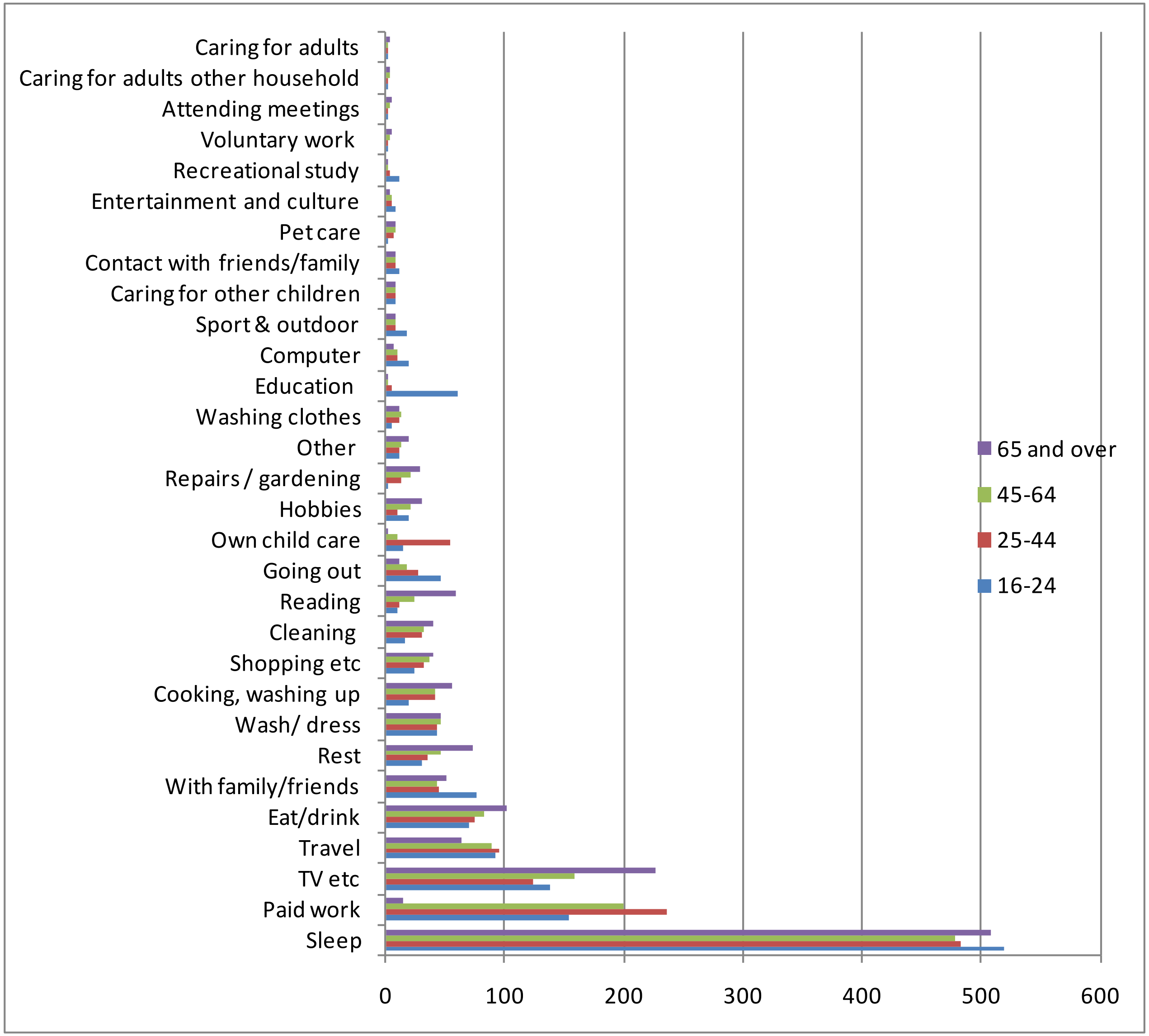
Water heat demand



Space heater emission



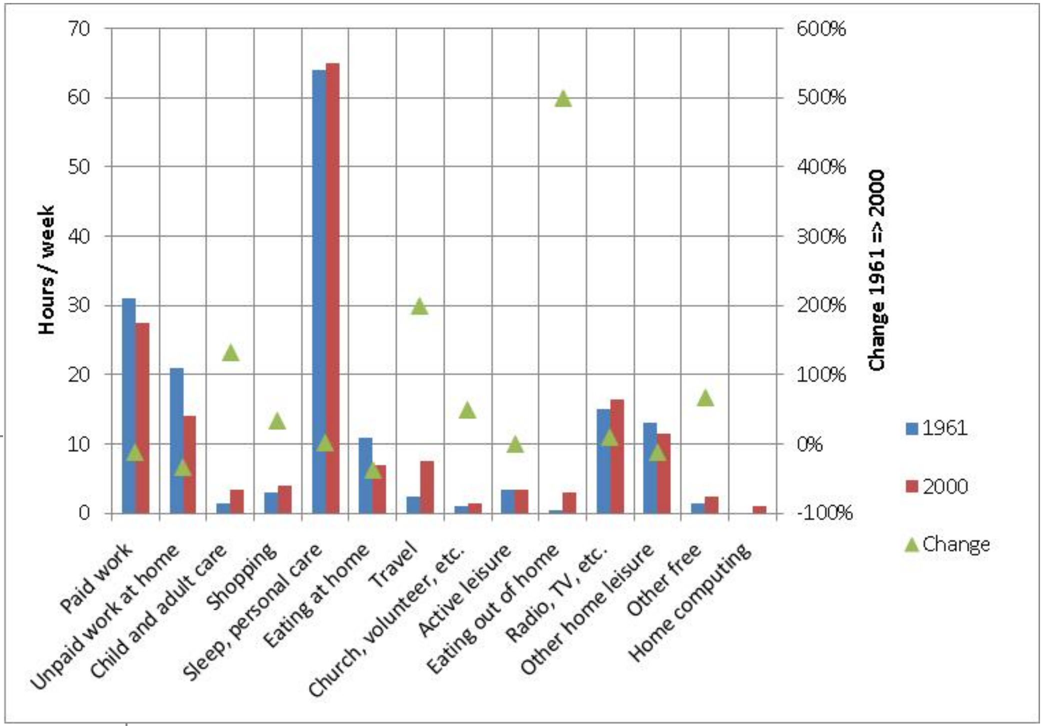
UK Personal time use : by age



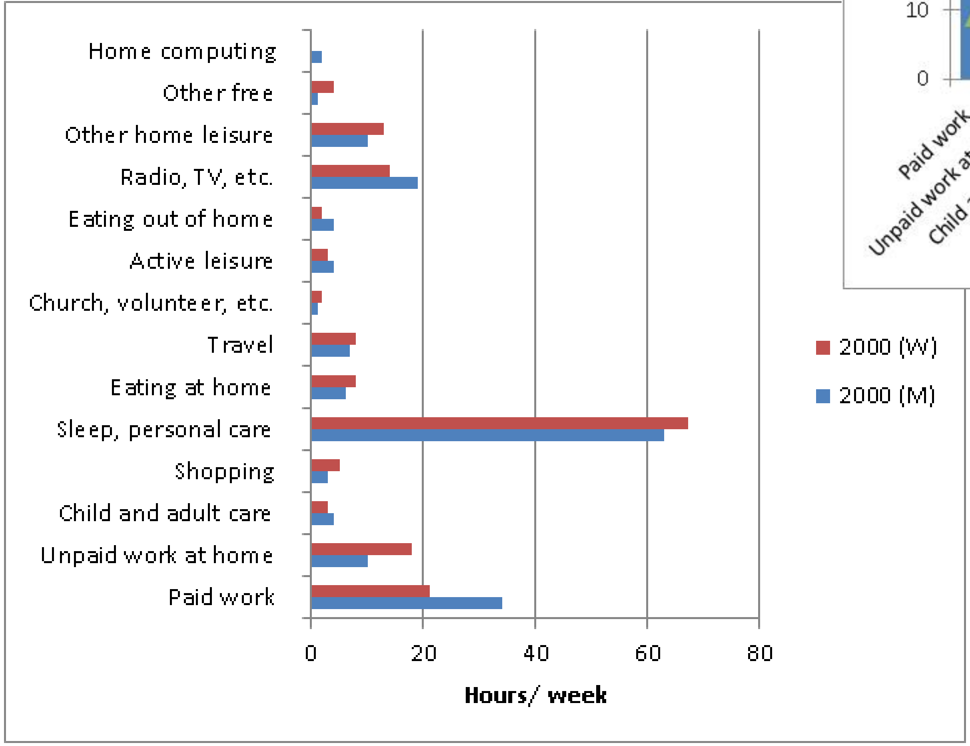
UK Personal time use : annual

Use of time varies:

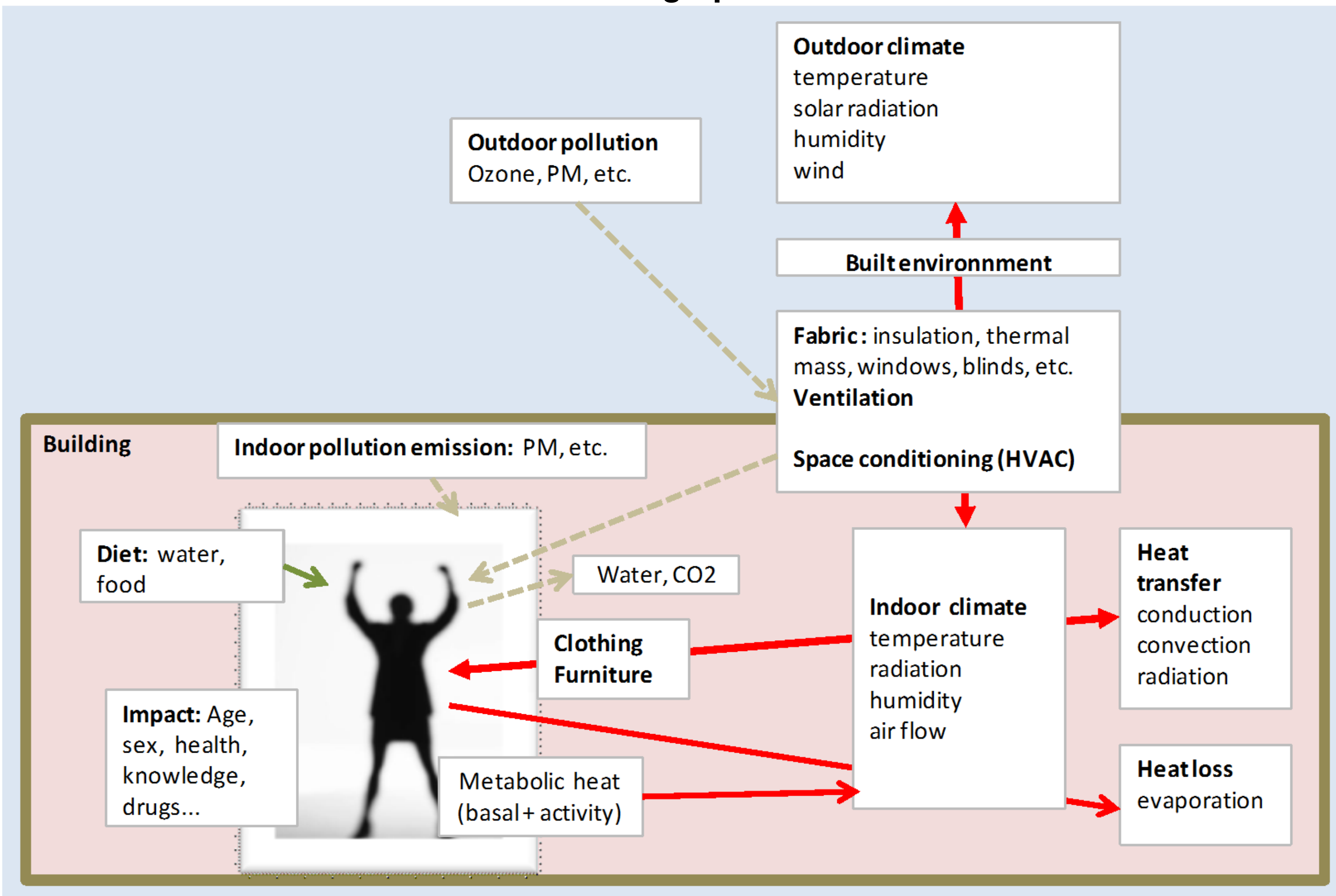
across the years



and by gender



Person in building : processes



Person-Dwelling Combinations (PDCs) - scenarios

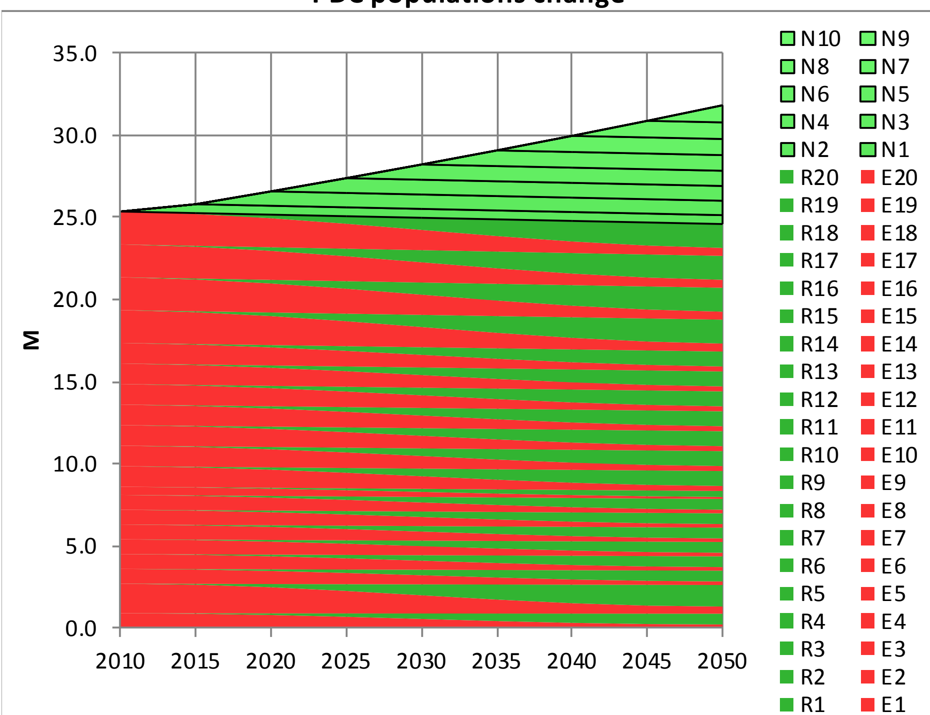
Numbers of PDCs changing with:

- Demolition
- Existing (E)
- Refurbishment (R)
- New build (N)

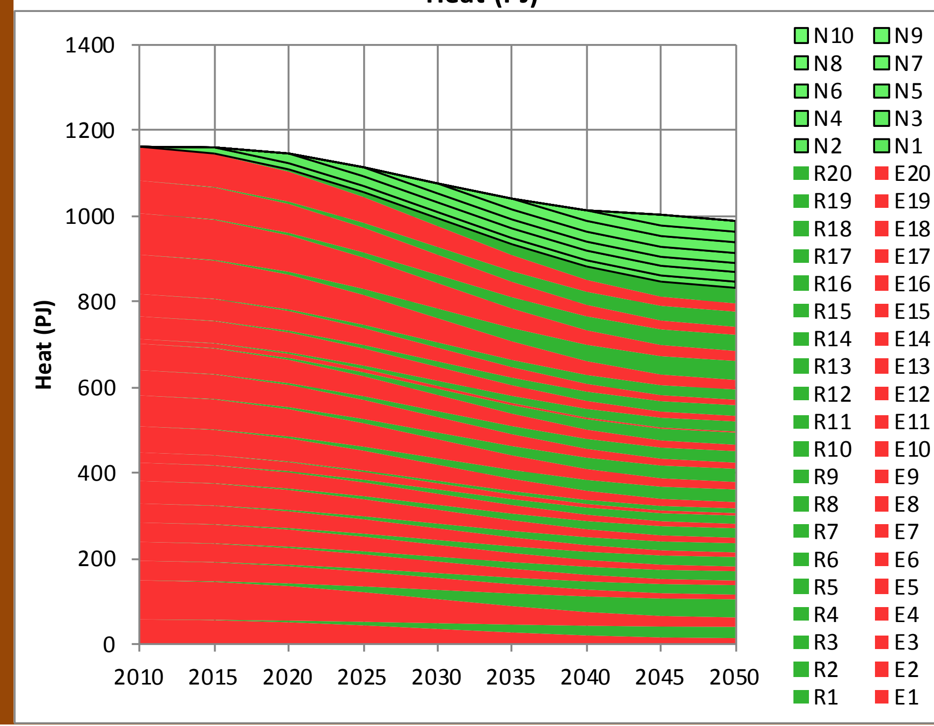
Space and water heat load of PDCs changing with energy efficiency

GBR: By 2050: demolish 3% Refurb 75%

PDC populations change



Heat (PJ)



Energy services

NEEDS	Task	Energy form	Technologies
Food	storage	heat (cold)	refrigerator
	cooking	heat	cooker
Comfort	shelter	materials	buildings
	thermal	heat (hot/cold)	heater/air conditioner
	lighting	light	light bulb (/daylight)
Hygiene	personal	heat	shower & boiler
	clothes	heat	washing machine
	dishes	heat	dishwasher/hands!
	house	power	hoover
Health	miscellaneous	miscellaneous	medical services
Culture	travel	power	vehicles
	telecommunications	electricity	telephone, internet
	electronic media	electricity	TV, hi-hi etc.
	miscellaneous		

SEE Energy Demand – socioeconomic future

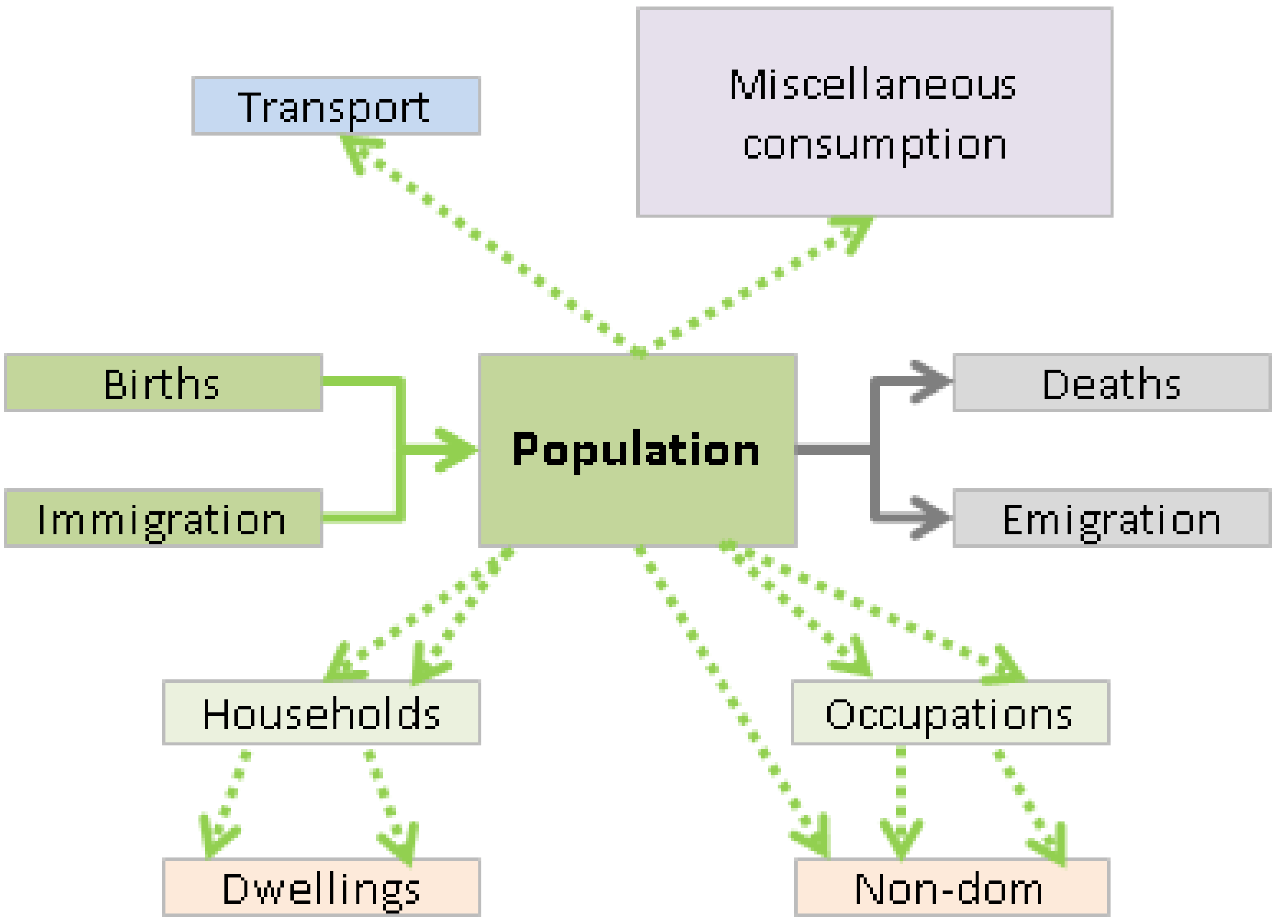
- How many people?
- How will they form households?
- Where will they live?
- What will they do?

Future demand: general considerations 2

Furthermore, energy consumption in the services sector and industrial sectors are themselves dependent on basic energy service demands. For example:

- energy consumption for administering public transport or aviation is dependent on the demands for those services;
- the energy consumed in the iron and steel or vehicle manufacturing industry depends on how many cars are made, which is scenario dependent;
- the energy consumption of manufacturing industry depends on how much loft insulation there is houses.
- The effects of energy demands on economic structure and its energy consumption are not considered here. (This is rarely analysed in energy scenarios because the effects of these structural changes and it is difficult to calculate them may be relatively small; .)

Demography and consumption



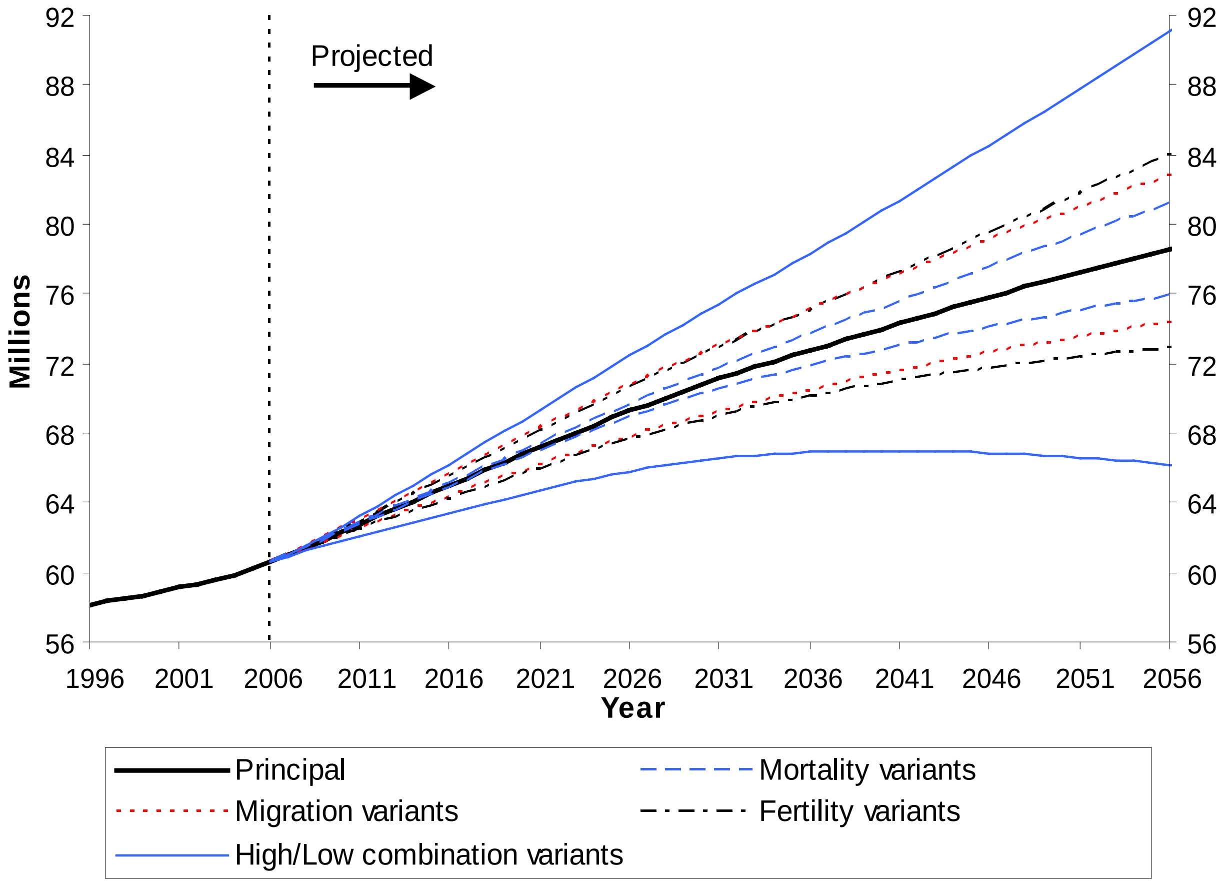
Demographic projections

Projections depend on assumptions about birth, death and migration.

These assumptions can change rapidly because of altered policy and other context, e.g. on:

- immigration
- health
- child support
- 'culture'

The National Population Projections indicate an uncertainty of 10-15% in the 2050 population with accompanying energy and emissions.



Source for projection: Helen Bray and Shayla Goldring, National Population Projections and the challenges of an ageing population.
www2.lse.ac.uk/socialPolicy/BSPS/ppt/2008_PP_Goldring.ppt

Also see: www.gad.gov.uk

A Demography model

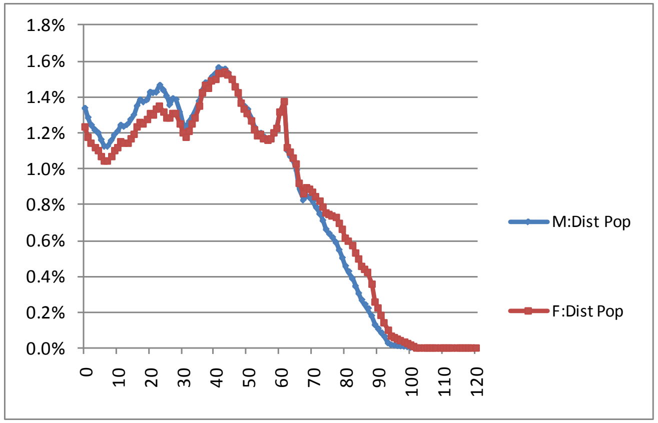
Variables	population	Np	million
	probability	p	0-1
	age	a	years
	gender	g	female/male
Probabilities	**these are variable across years**		
	birth	Pb(a,g)	g=f
	birth gender	Pg(a,g)	a=0 to 1
	death	Pd(a,g)	
	immigration	Pi(a,g)	
	emigration	Pe(a,g)	

Population evolution from t to t+1

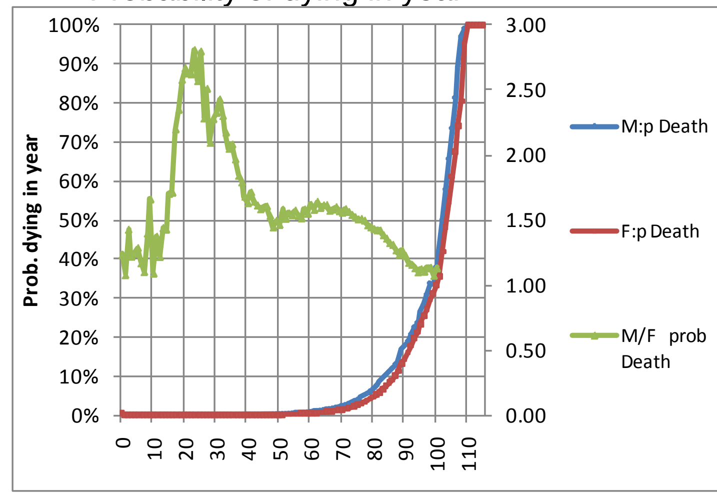
$$Np_{t+1}(a,g) = Np_t(a,g)[\,Pb(a,g)*Pg(a,g) - Pd(a,g) + Pi(a,g) - Pe(a,g)]$$

Demography model inputs and outputs (UK)

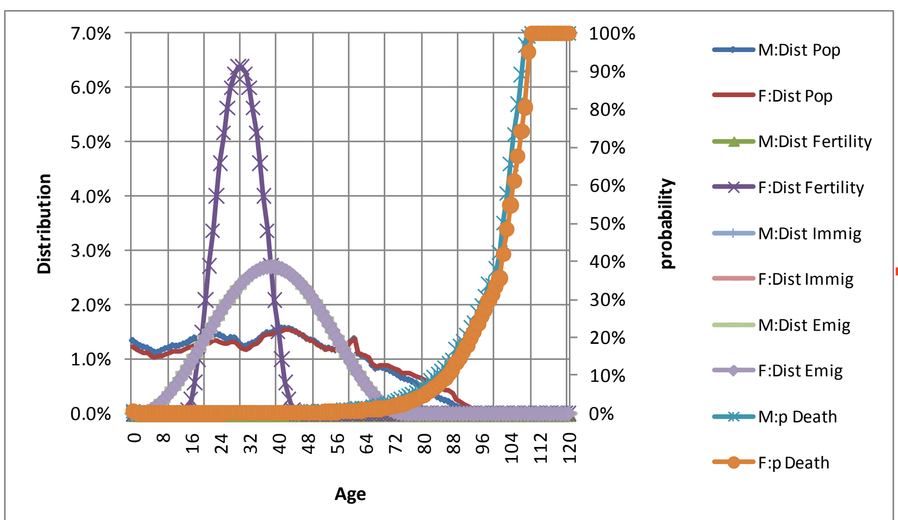
Age distribution by sex, 2008



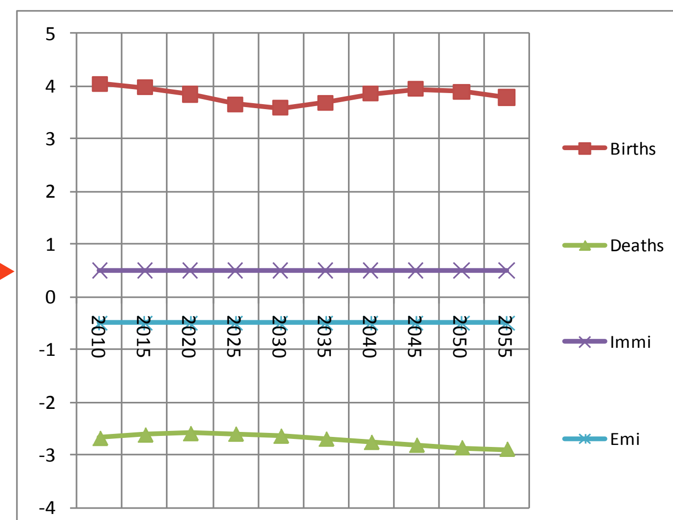
Probability of dying in year



Population change: birth, death, migration probabilities



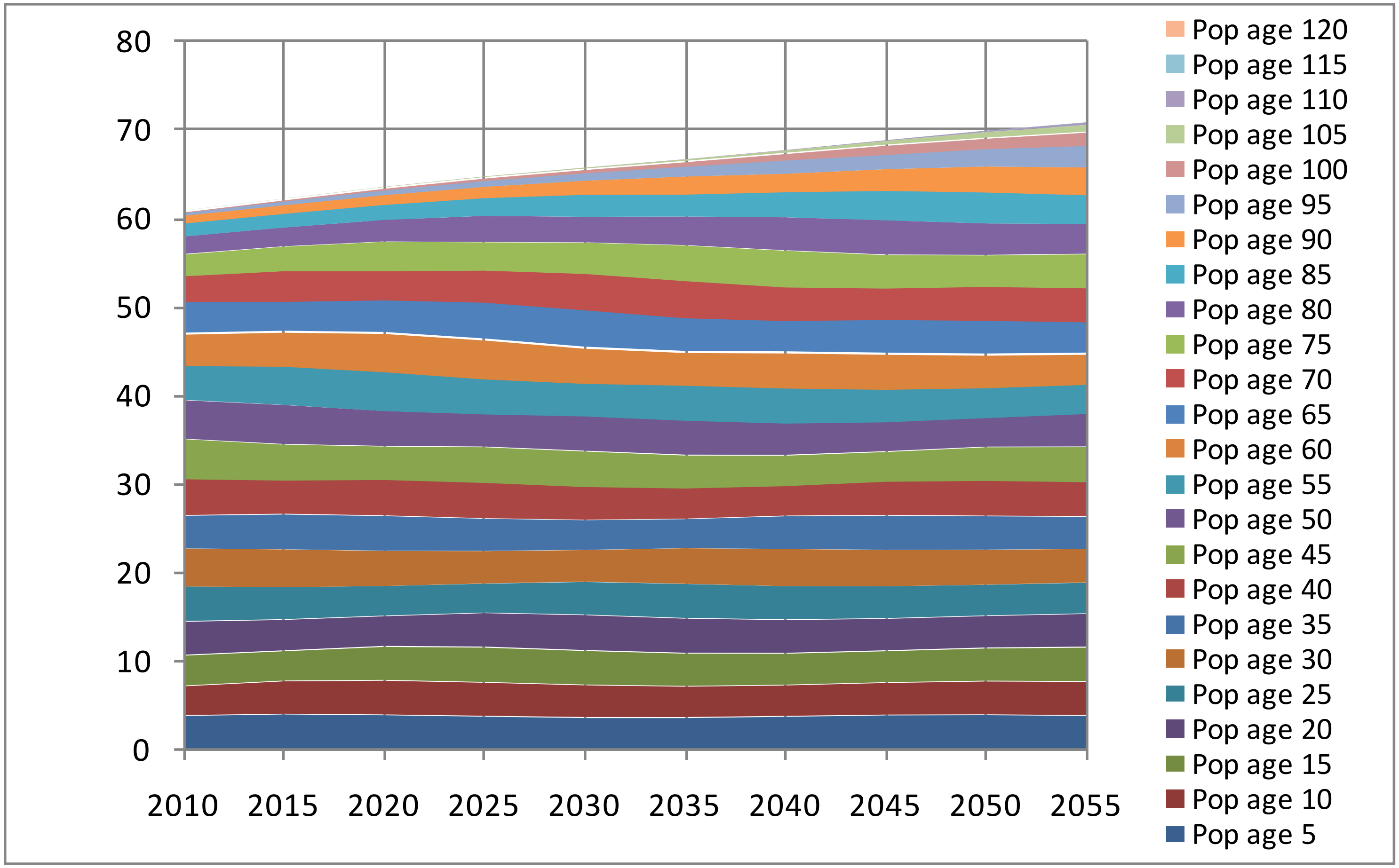
Population change: birth, death, migration changes



Future UK demography: population and age

Population forecasts change rapidly; latest higher growth because of more immigration and higher fertility.

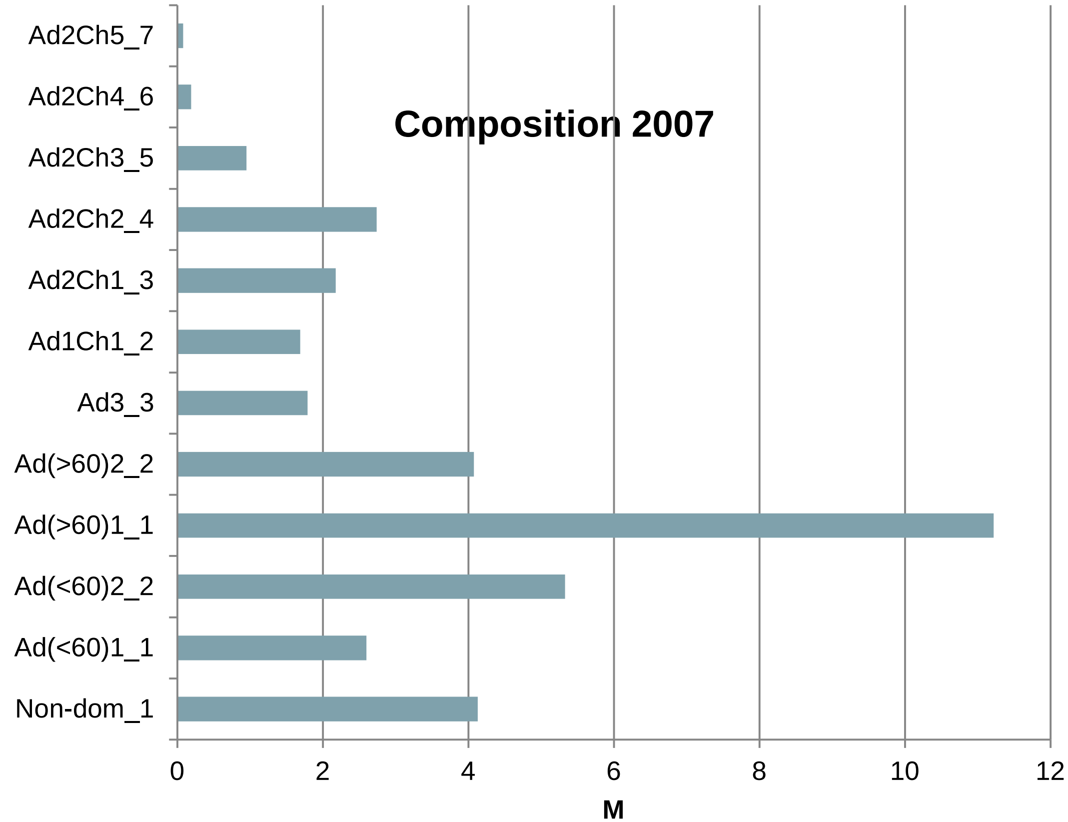
Very probable growth in relative numbers of older people.



Household formation

Given a population how will it form households of different compositions?

- different numbers of Adults (over and under 60), and Children
- wealth
- activities



Household formation model

Assume allocation of people to households based on history or some assumed changes in the future

Households

households	Nhh
household type	h
allocation of population	Ph(a,g,h)

Number of households

$$Nhh\ t\ (h) = \ Np\ t(a,g)\ *\ Ph(a,g,h)$$

Dwelling stock model

How will dwelling stock evolve with households?

Physical

- Location
- Form – detached, semidetached, terrace, flat, residential
- Size – number of bedrooms etc.
- Efficiency – insulation etc.
- Energy system – boiler, heat pump, etc.

Need some mapping of households on to these variables, e.g. for form.

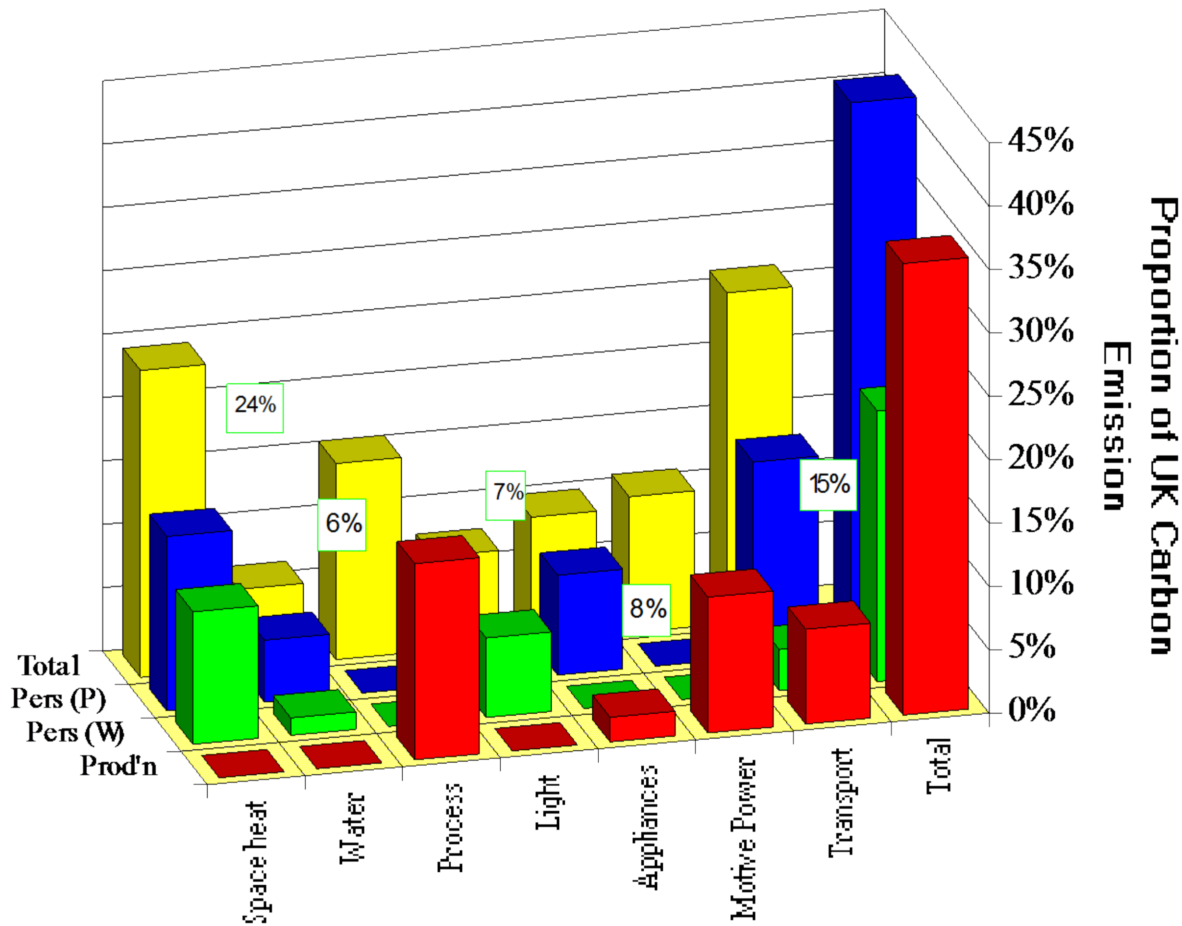
Dwellings	dwellings	Nd	million
	form	f	
	allocation of household	Pf(h)	
	Number of dwellings		

$$Nd(f) = \sum [Nhh(h) * Pf(h)]$$

Carbon emission by energy service

Energy and carbon incurred:

Pers(P)	Personal private consumption of at home and travelling
Pers(W)	Personal at work
Prod'n	In production of goods and service



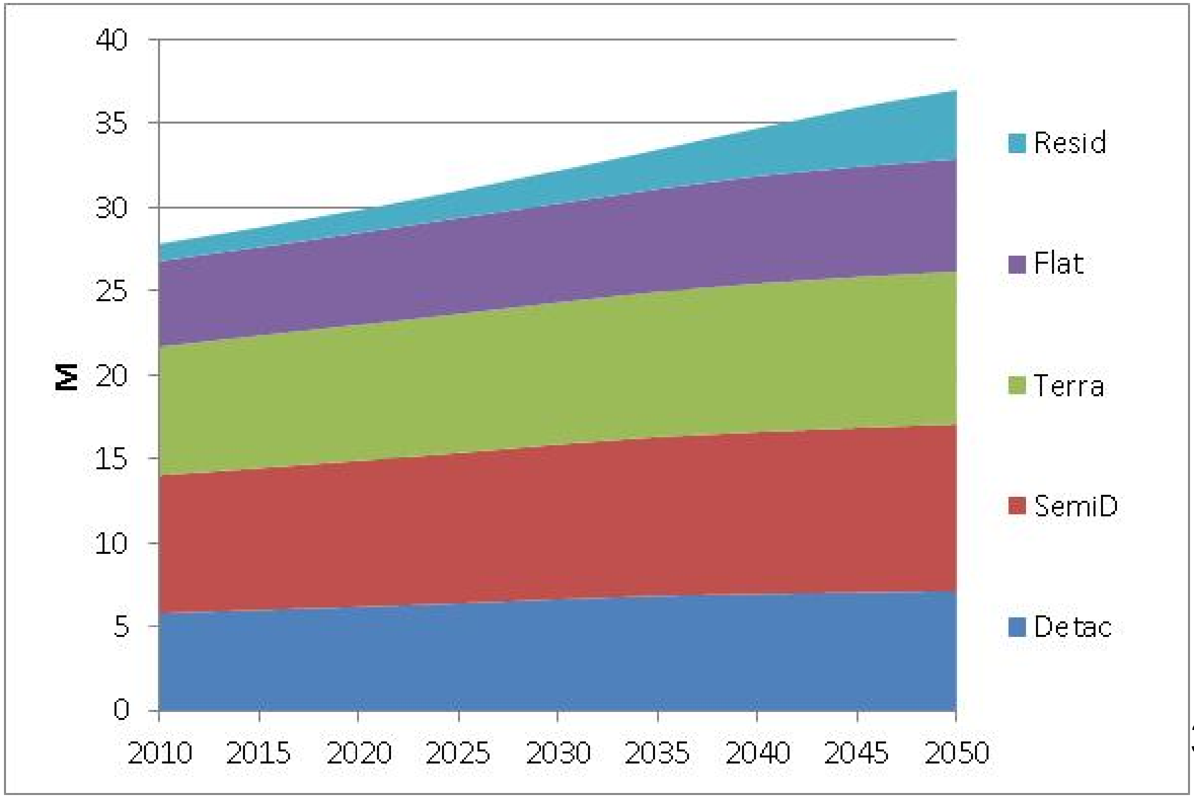
Future UK dwellings: built form

How will the stock be altered and used to accommodate different households?

- What social dynamics? - e.g. older people often have capital and retain large family houses after children have left.

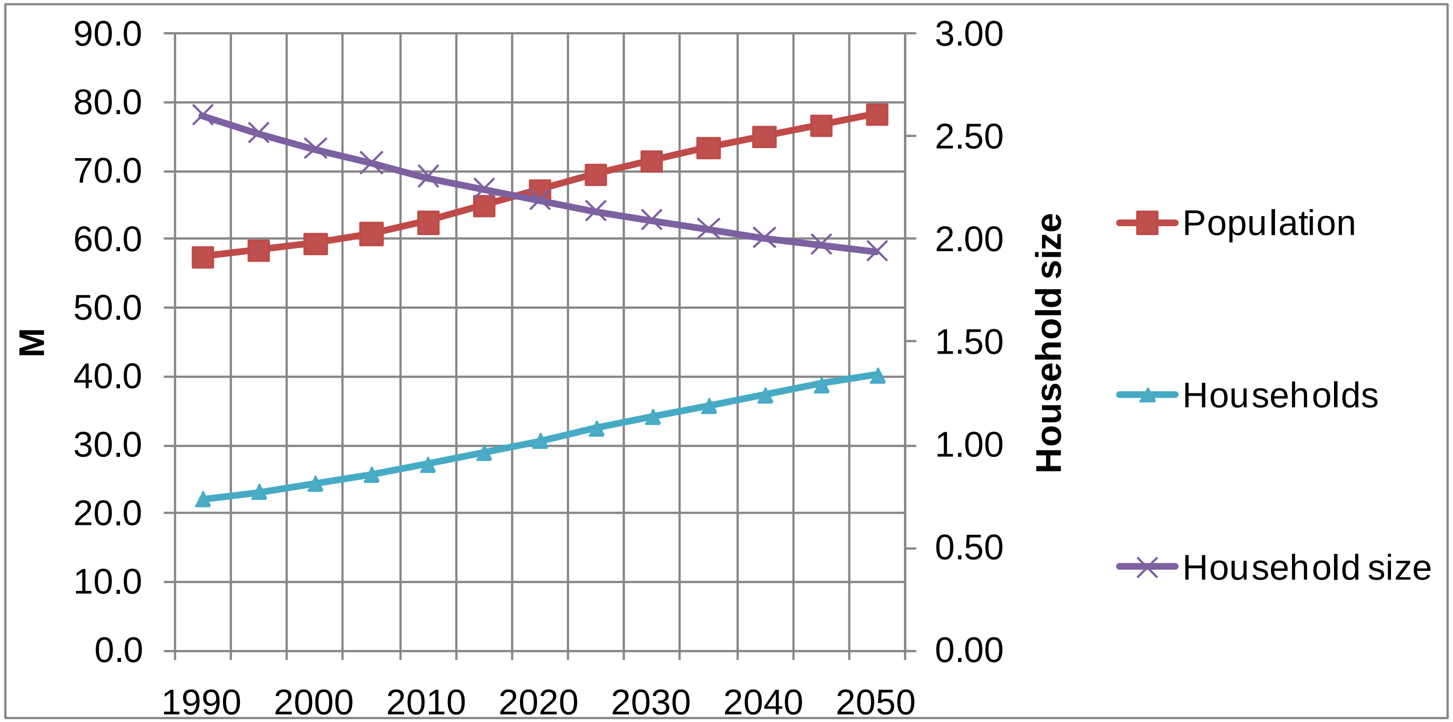
Effects of drivers:
- increasing wealth
- Increasing age
- Energy costs

Projection of dwellings from households Assuming unchanged population=>household probabilities



Future UK population, households and household size

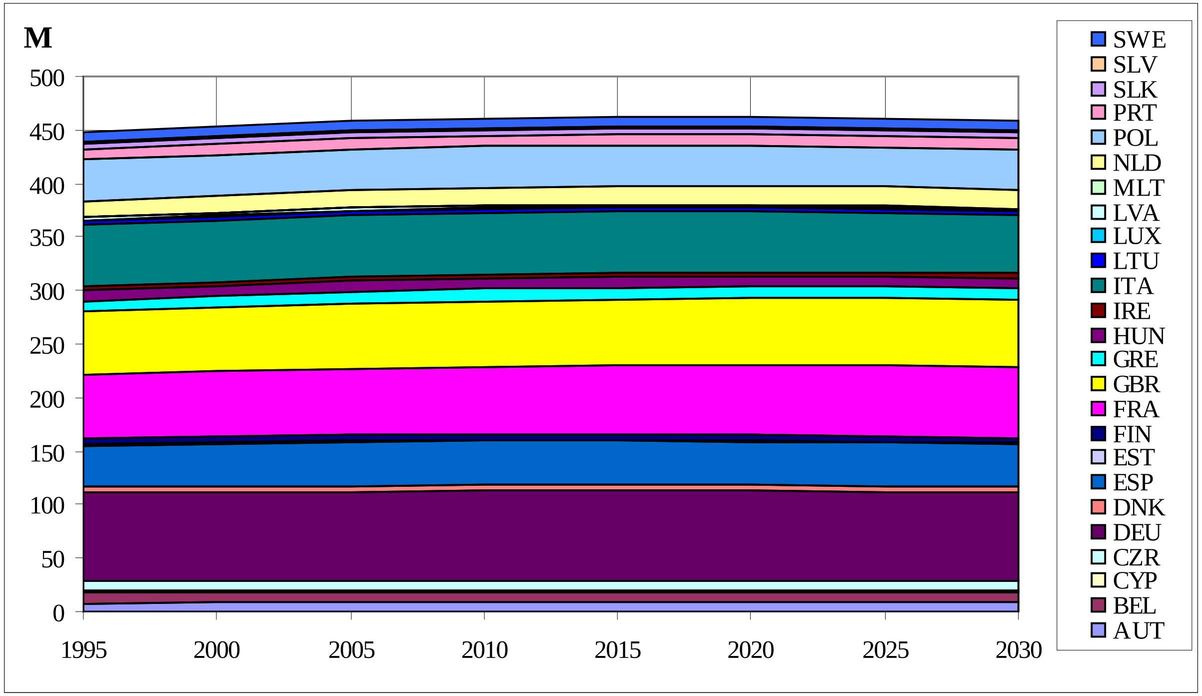
- More people
- smaller households
- more dwellings
- more energy per person



Future building needs: EU population

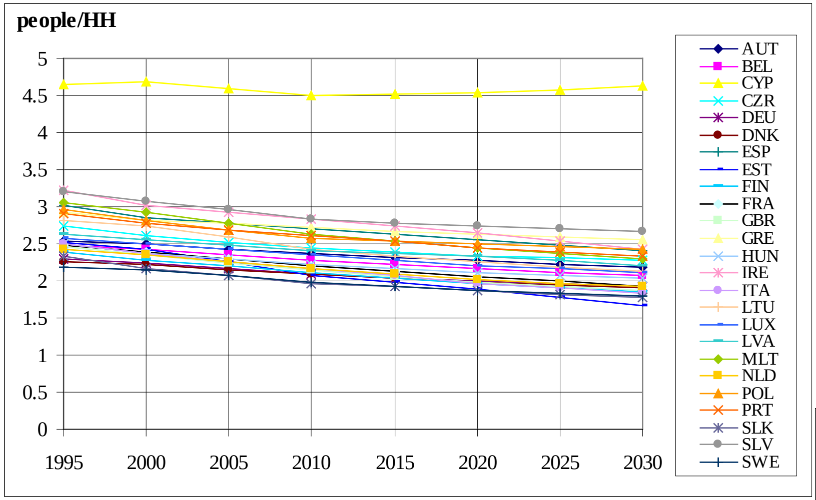
Europe and global population stabilising over next 15-60 years

Europe population forecast – peaking around 2015

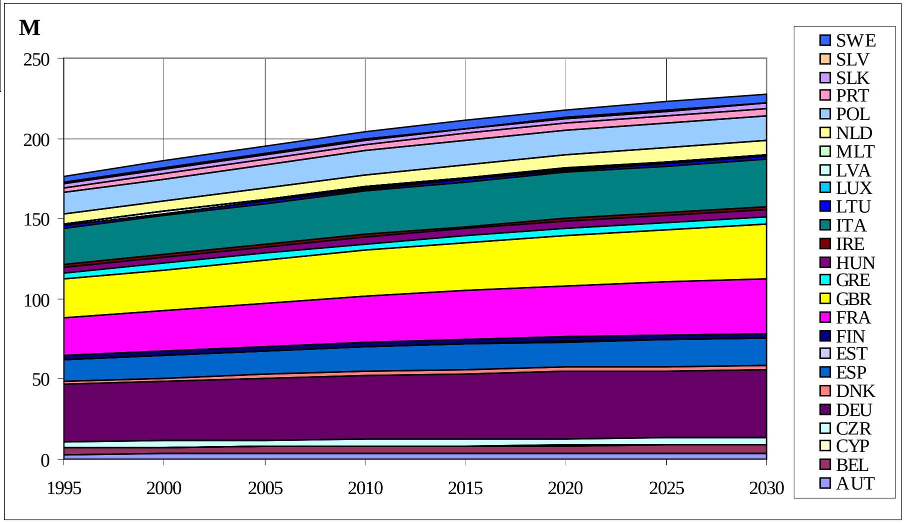


Future building needs: Europe households

Smaller households



More households



World building needs

Ageing population everywhere

Less developed regions

- **Population growth** about 3 billion (40%) percent to 2050
- **number of households** will grow by about 1.6 billion (80 %) - decreasing household size a factor.
- Rapid urbanisation. China +0.4 billion more urban dwellers in 20 years; India, similar trend

Developed regions

- nearly static