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Resilient Electricity Networks for Great Britain

(RESNET)

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Project Aim

To develop and demonstrate a systems-level approach to analysing, at the GB scale, the resilience of existing and proposed electricity networks to a changing climate, including societal and technical adaptation.

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Project Team

Multi-disciplinary expertise from Manchester & Newcastle

- University of Manchester:
  - Kevin Anderson, Ruth Wood, Dana Abi Ghanem, Sarah Mander, Stephen Glynn, Clair Gough (Tyndall Centre for Climate Change)
  - Ian Cotton, Pierluigi Mancarella, Xiaolong Hu (Electrical Engineering)
  - John Moriarty, James Blair (Mathematics)
- University of Newcastle
  - Sean Wilkinson (Structural Engineering), Richard Dawson (Earth Systems Engineering), Gaihu Fu (Infrastructure Resilience), Lucy Manning (Climate Change), Chris Kilsby (Climate Change)

Project part funded by National Grid

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RESNET Comprises 5 Work Packages

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WP1: Spatial Climate Scenarios

- Future climate scenarios generated using UKCP09
- Emphasis on extremes & climate change disrupting large areas
- Model temperature, rainfall, flooding & wind speed
- Timescales of 2020, 2050, 2080

Objectives:

- *To develop a weather generator for producing scenarios of spatially coincident weather extremes in future climates at a national scale*
- *To apply a weather typing approach to the regional climate models used by UKCP09 to produce a wind storm component for the weather generator*

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WP2: Future Energy Scenarios

- Generate ***energy*** demand & supply scenarios for 2C, CCC & BAU emissions
- Detail the ***electricity*** dimension of the energy scenarios
- Focus on 2020, 2030, 2050 and 2080s timeframes
- Consistent with UKCP09 climate scenarios *(plus, 4C by 2050)*

Objective:

To generate spatially and temporally resolved scenarios of future electricity demand and supply, with different scales of decentralisation

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WP3: Network Performance Analysis

- Develop component models for use in probabilistic power system analysis
- Examine changed performance (impact of climate on rating)
- Represent component failures (from failure data, modelling & stakeholders)
- Characterise future / emerging technologies

Objective:

To develop models relating changes in the severity of weather related events to performance / failure rate of individual network components; and to identify measures that can improve the future performance of equipment

WP4: Quantified Analysis Of Resilience & Effectiveness Of Adaptation

- Estimates of climate change impacts on day-to-day performance of grid,
- Existing grid used as benchmark
- Climate change impact quantified wrt. cost, maintenance, demand, outages, etc
- Critical system aspects / components quantified

Objective:

To quantify the potential impacts of future climate on the operational and infrastructure resilience of the overall GB power system

WP5: Social Responses To Adaptation Measures

- Societal adaptation measures considered alongside technical
- In-depth interviews to scope knowledge on electricity shortages etc
- Perceptions of the adaptation measures (& impacts) identified

Objectives:

To explore the societal implications and identify potential barriers to measures intended to make the grid more resilient to climate change

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Intended Outcomes

- A description of how climate may impact the transmission system
- Outline opportunities for addressing such impacts
- Understand risks posed by climate change to system components
- Recommend spec' of equipment for future-proofing
- Propose network configurations for reducing climate impacts
- Understanding how society may respond to grid adaptation measures

WP2 RESNET Scenarios
Framing and approach

Kevin Anderson
Steven Glynn, Ruth Wood – Quantitative
Clair Gough, Sarah Mander - Qualitative

Tyndall Centre
for Climate Change Research

Scenario Scope

- Energy system – electricity and non-electricity
- Energy use across all sectors (inc aviation/shipping)
- Timeframes: 2020, 2030, 2050, 2080
- Temp' by 2050; 2C and 4C

well above A1FI & Betts carbon cycle feedbacks;
latest CO2 emissions, global ~6% rise, UK ~4% rise

Boundaries of the scenarios:

- All UK energy system *(electricity, heat, transport – inc. international)*
- Demand & Supply
- Timeline *(now to 2080 – as a pathway not end point)*
- Low carbon (from 2°C to statutory carbon budgets)
- Affordable and secure/resilient energy *'services'*

Outline of method:

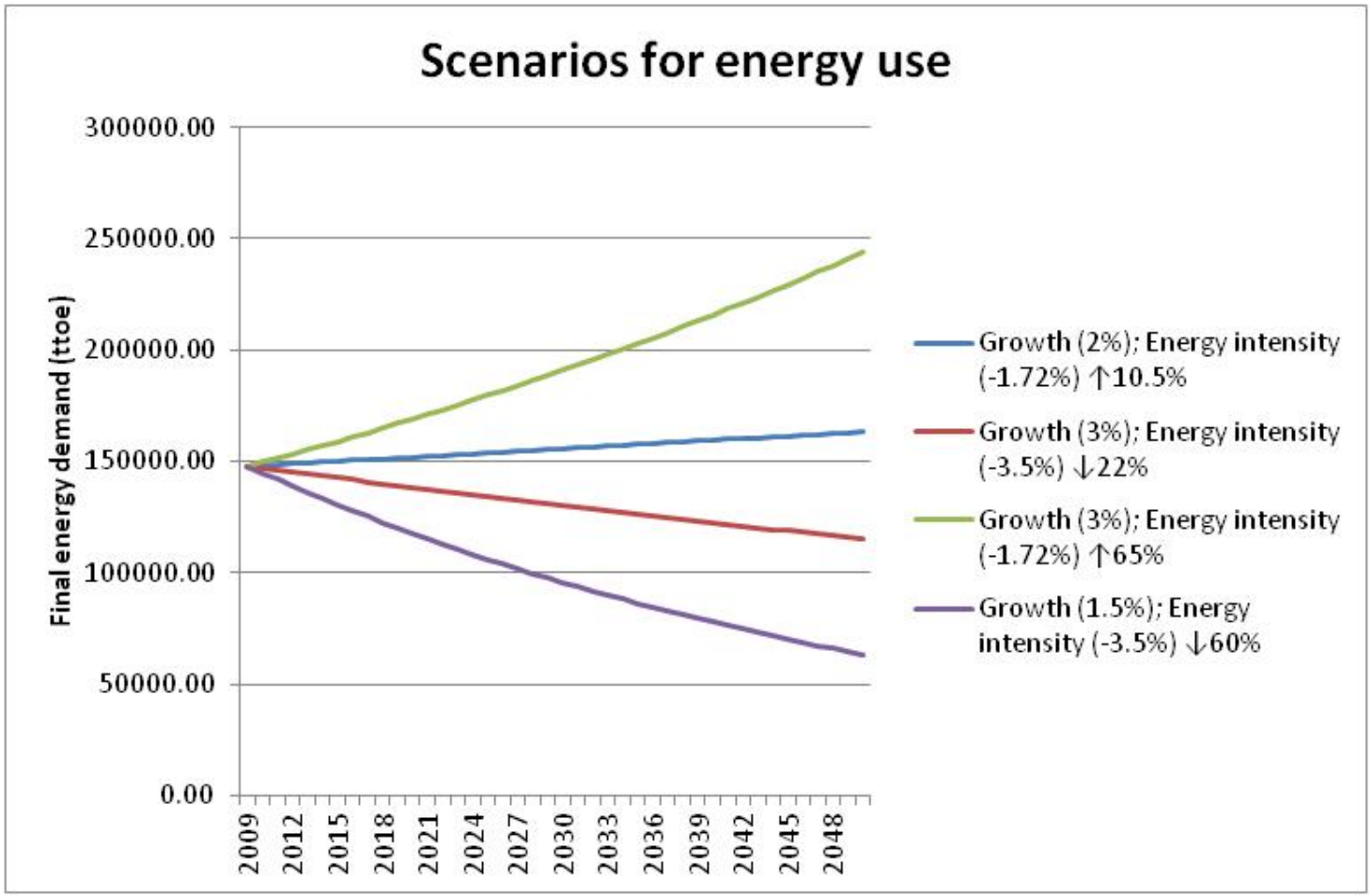
- Use ASK to develop suite of alternative energy scenarios for UK
- Different to UKERC, CCC, etc, as:

  -bottom-up technology & user driven (c.f. top down economic modeling)
  -pathways and phased transitions rather than endpoints
  -carbon budgets and not 2050 reduction targets
  -much higher electricity penetration
  -greater range of final energy use
- Balance supply & demand (with consideration of storage)
- Analyse energy system as dynamic (active & passive management)
- Stakeholder engagement throughout (industry, regulators, policy)

Carbon Basis

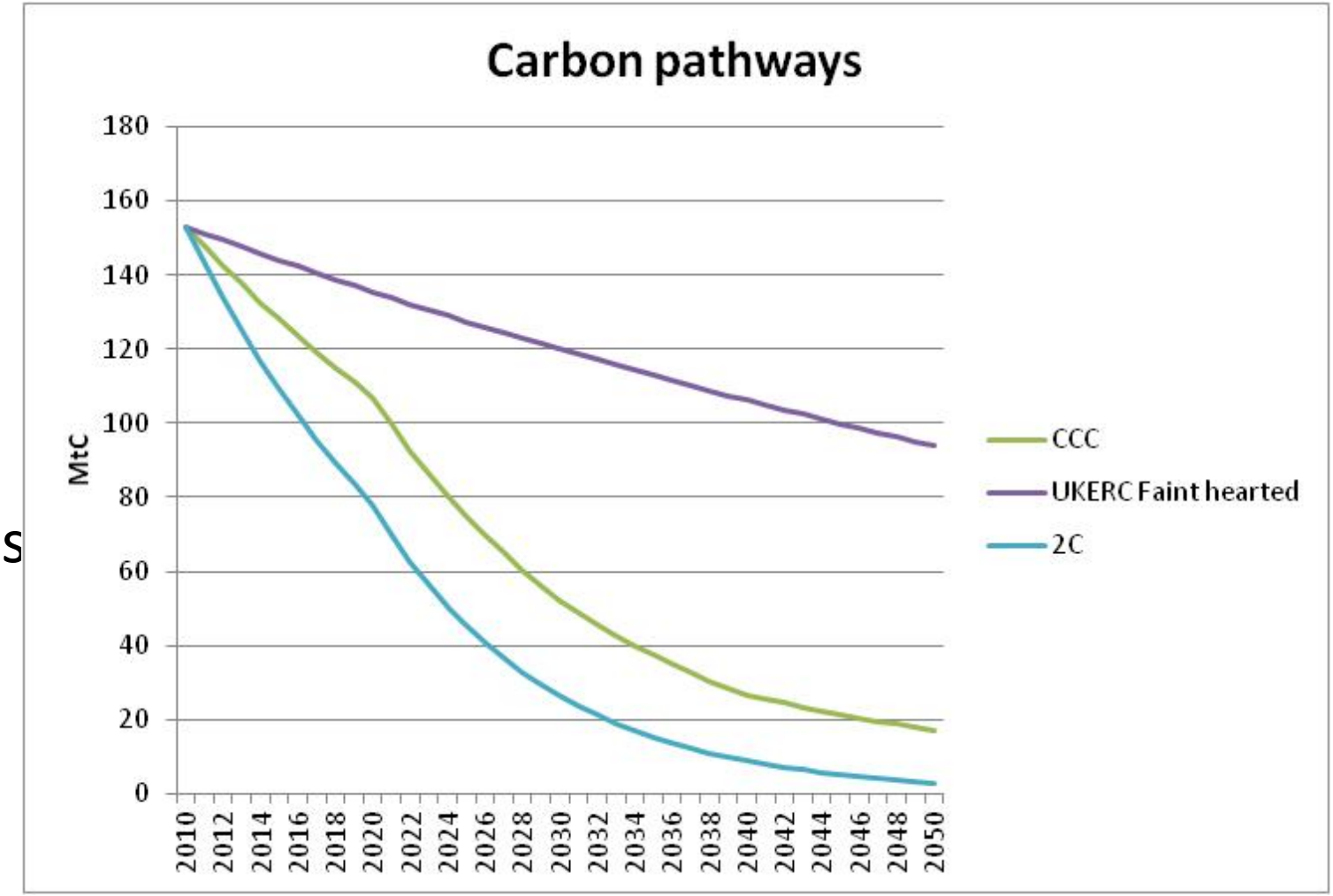
Framing the scenarios

Different levels of energy demand

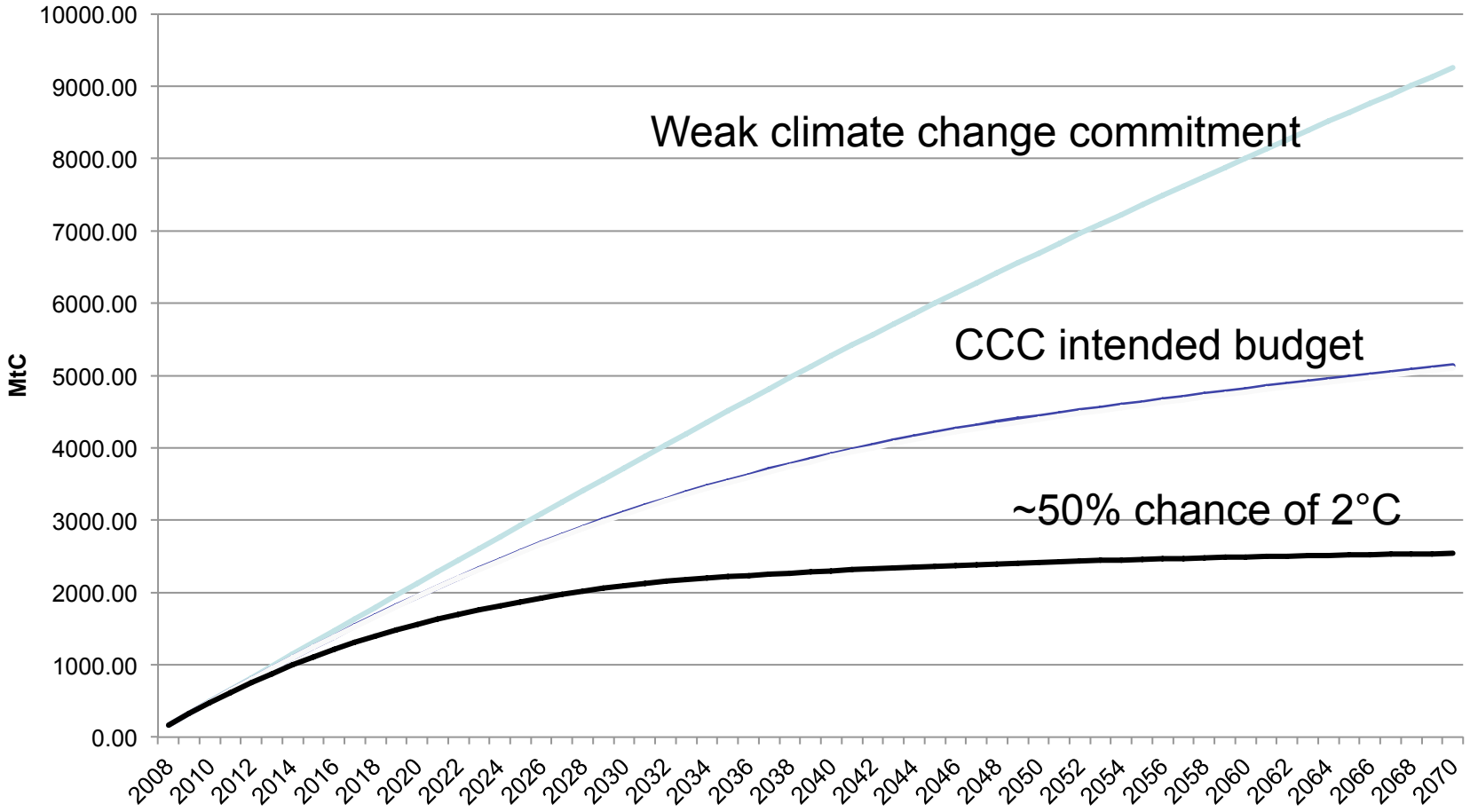


Framing the scenarios

Different levels of carbon reductions



Cumulative Carbon emissions for each scenario



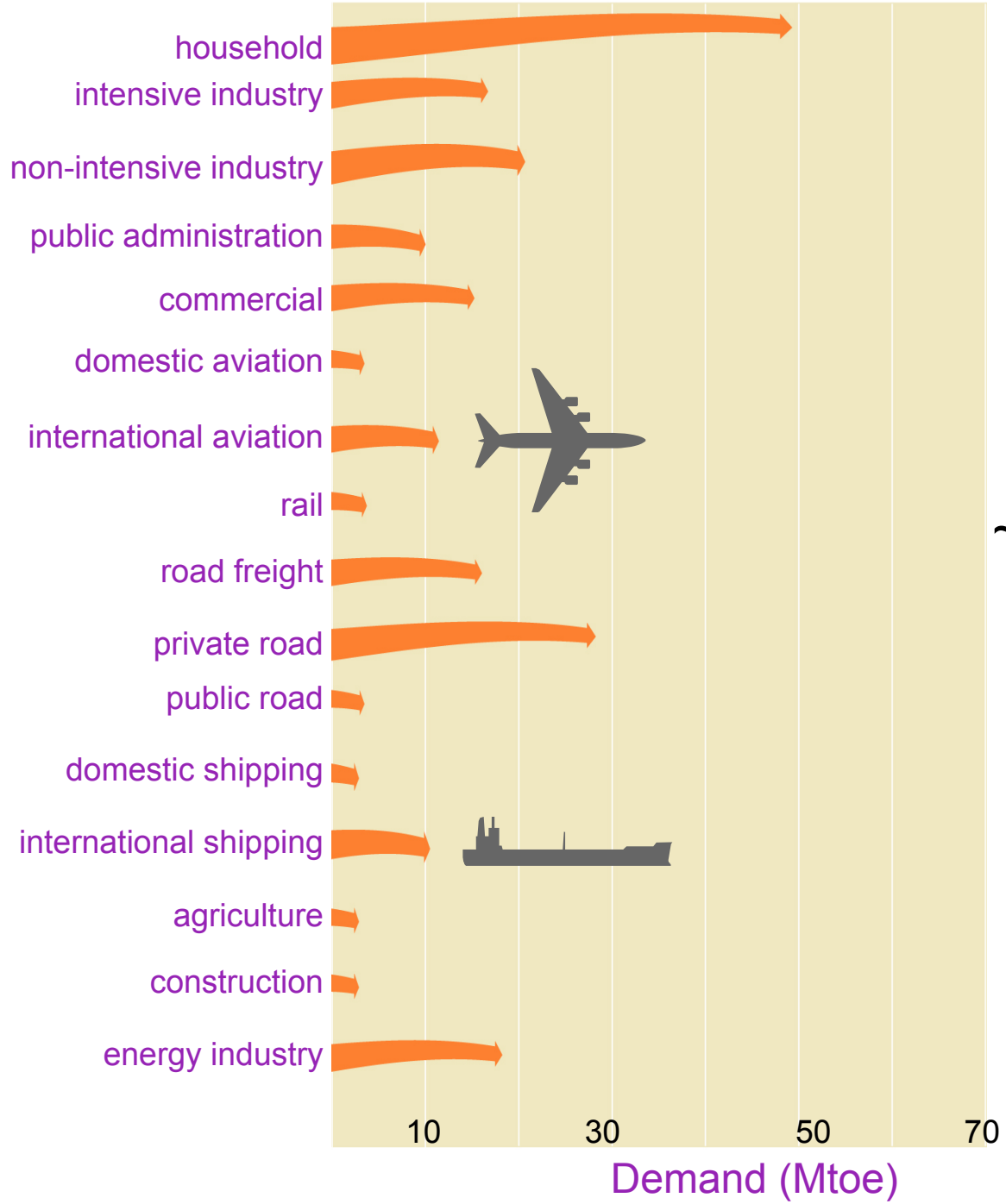
Differentiating electricity from energy

Energy scenarios translated into *electricity* scenarios; build on previous & CCC's analysis; headline electricity figures for the scenarios:

- ***Low electricity consumption*** ***300TWh by 2030 and static thereafter***
- ***Medium elec' consumptions*** ***600TWh by 2030 to 800TWh by 2050***
- ***High elec' consumptions*** ***1000TWh by 2030 to 1500TWh by 2050***

Proportion of energy met by electricity, level of intermittency, active demand, EVs, heating, storage, spatial distribution etc vary between/within scenarios,

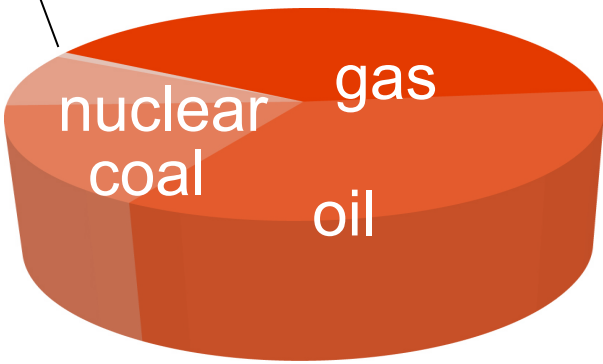
ASK energy system ‘model’



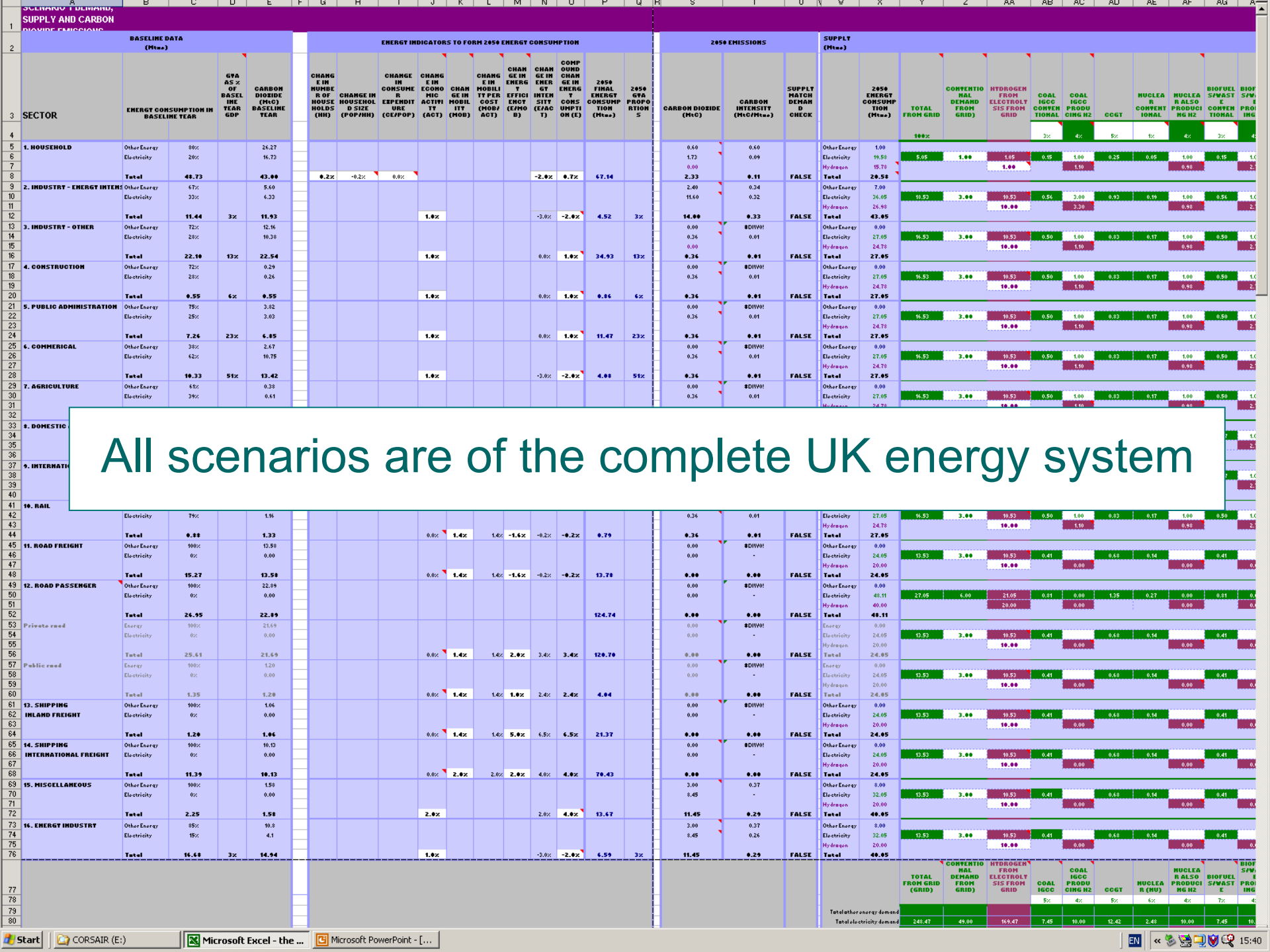
‘Today’

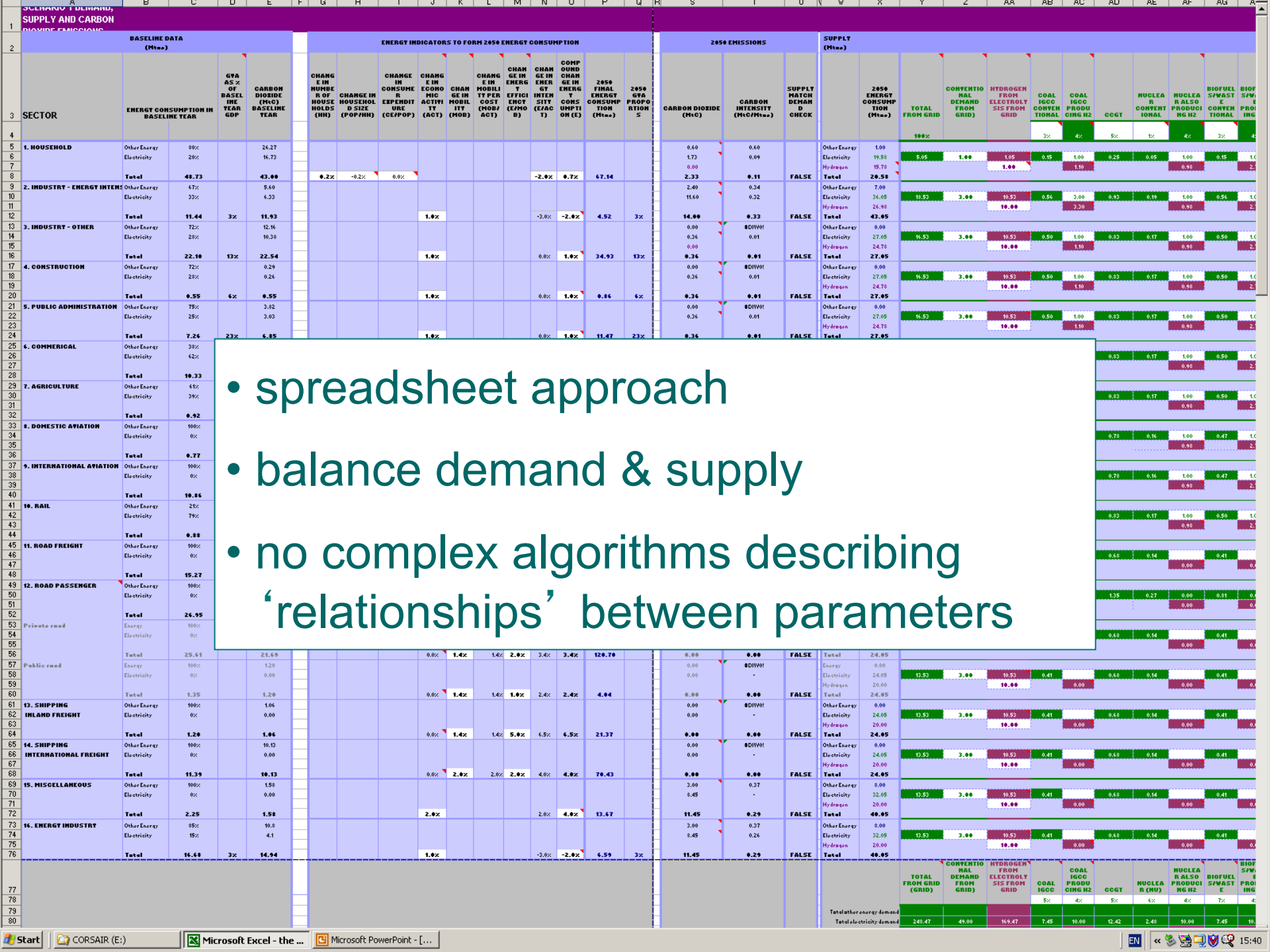
Primary energy demand: baseline

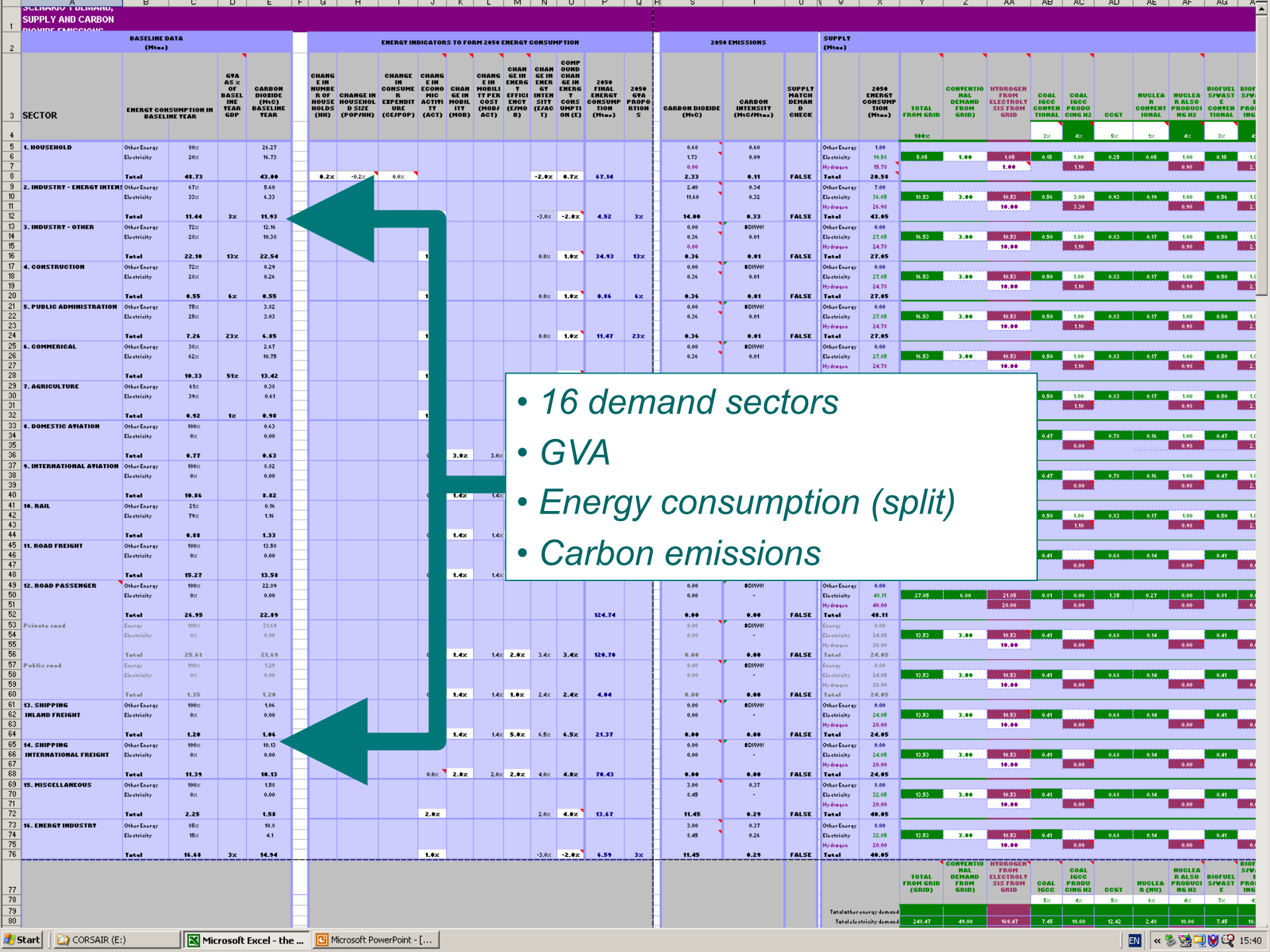
~1% renewables

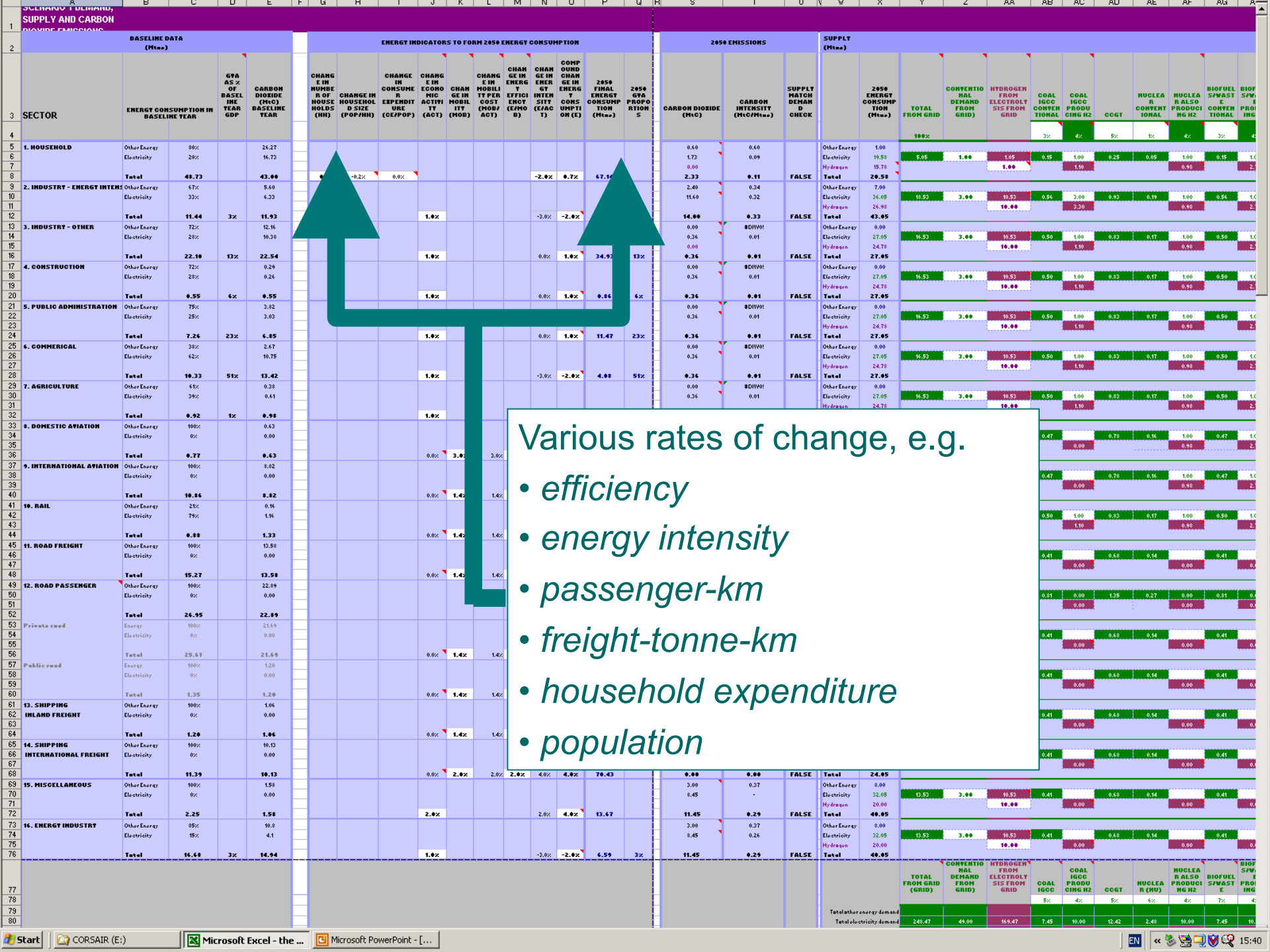


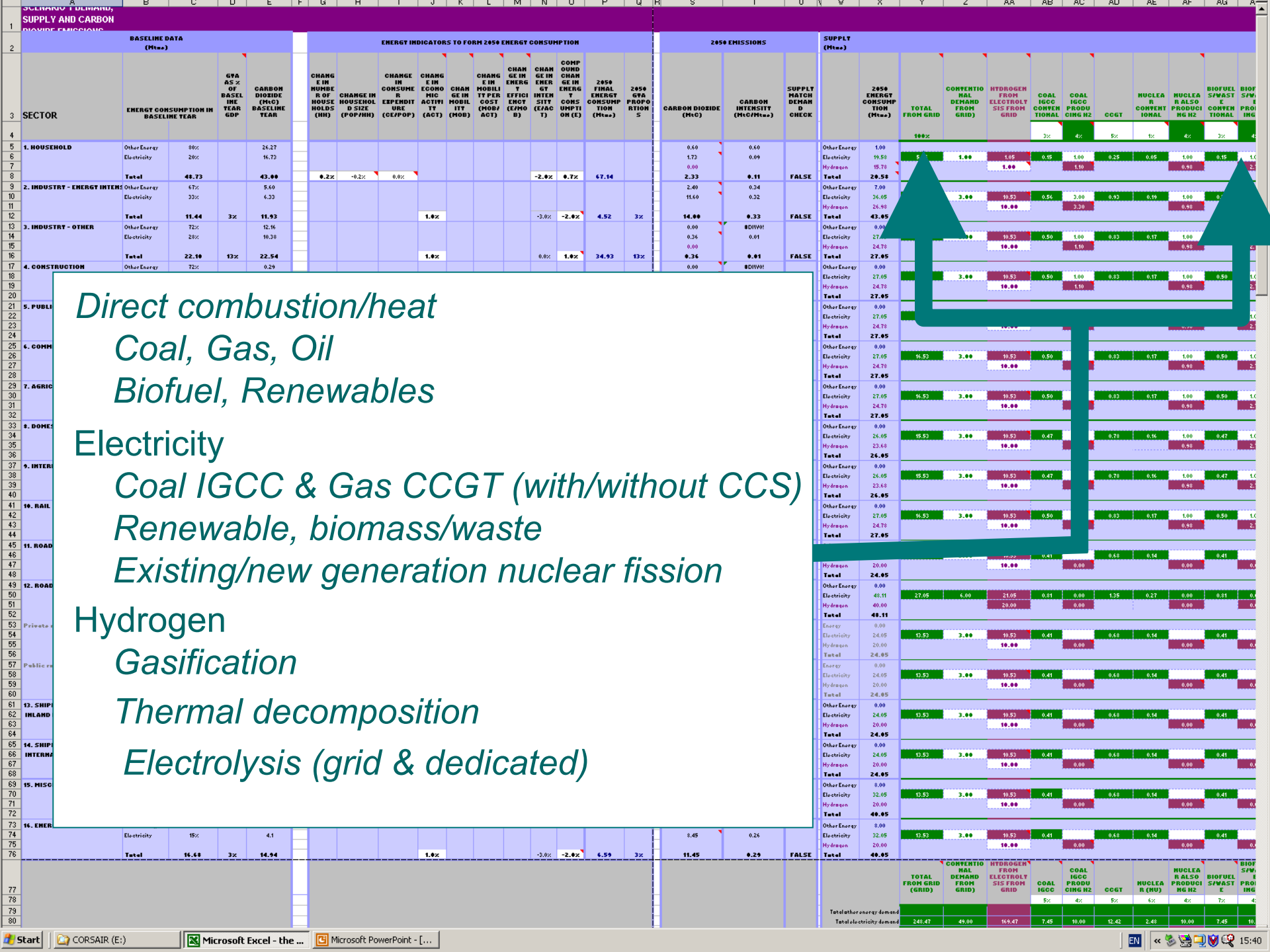
~ 20% electricity

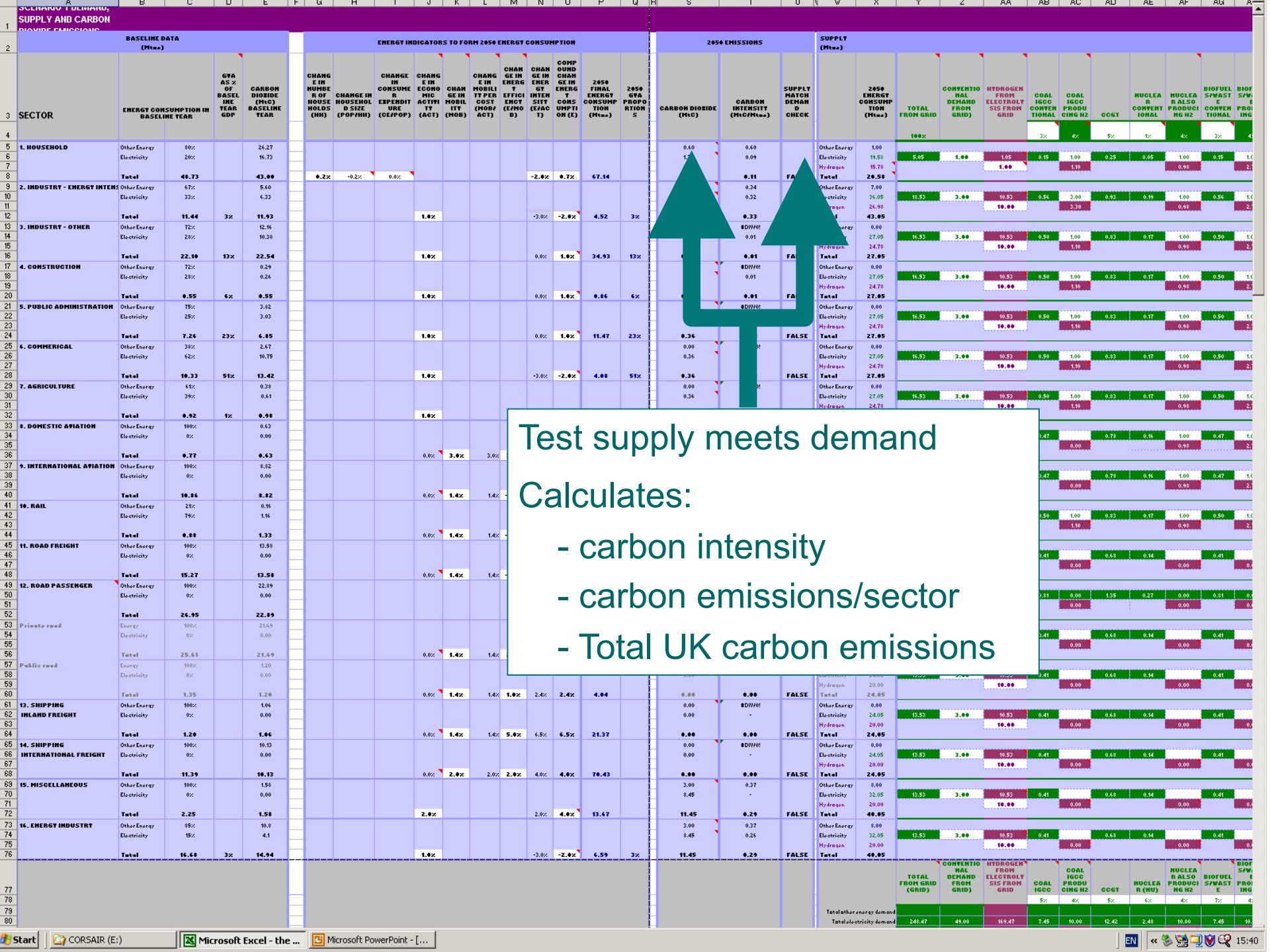

All scenarios are of the complete UK energy system

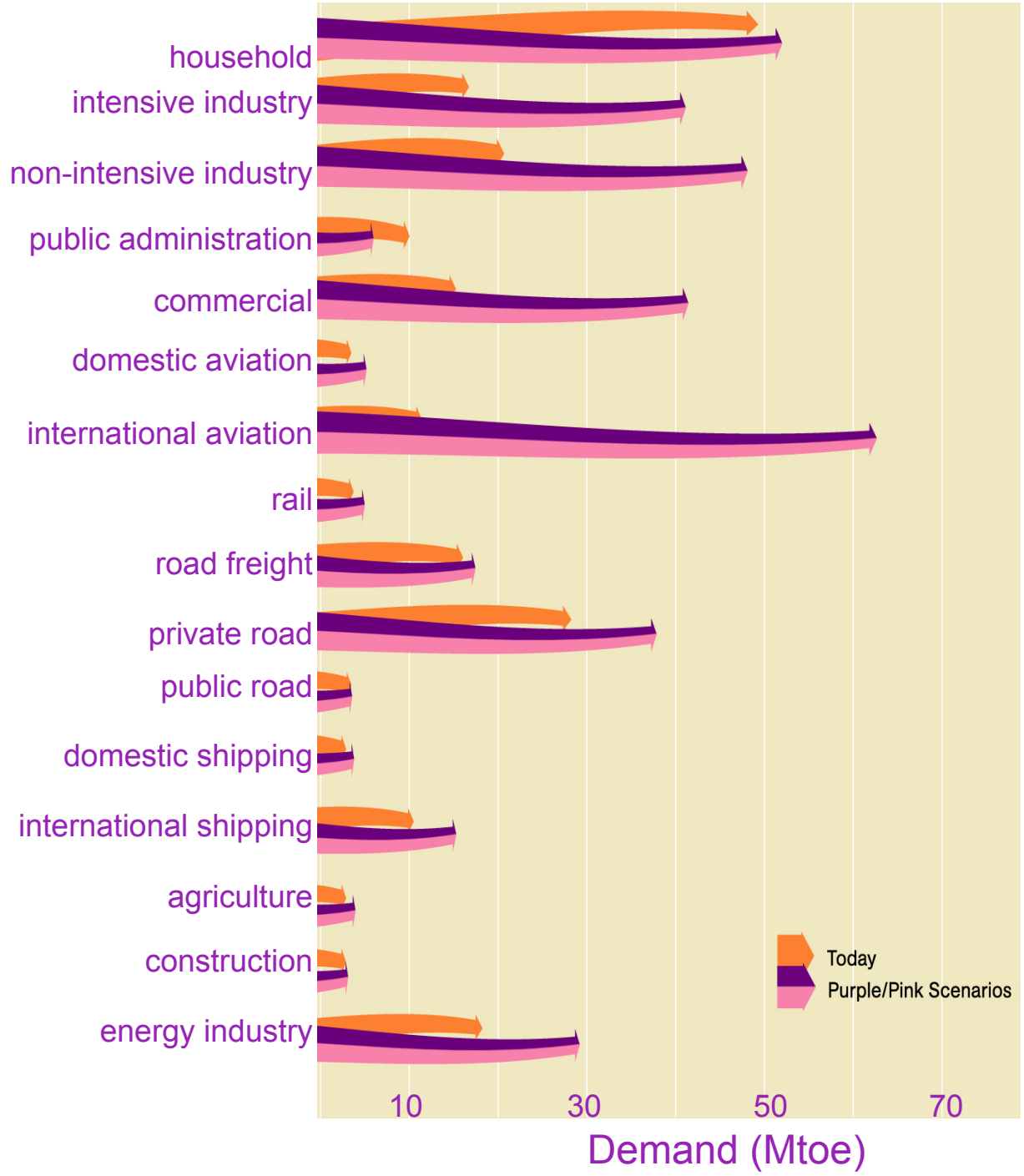

• spreadsheet approach
• balance demand & supply
• no complex algorithms describing ‘relationships’ between parameters


• 16 demand sectors
• GVA
• Energy consumption (split)
• Carbon emissions


SUPPLY AND CARBON
BASELINE DATA (Mtoe)
EMERGY INDICATORS TO FORM 2050 EMERGY CONSUMPTION
2050 EMISSIONS
SUPPLY (Mtoe)
SECTOR
1. HOUSEHOLD
2. INDUSTRY - EMERGY INTENSIVE
3. INDUSTRY - OTHER
4. CONSTRUCTION
5. PUBLIC ADMINISTRATION
6. COMMERICAL
7. AGRICULTURE
8. DOMESTIC AVIATION
9. INTERNATIONAL AVIATION
10. RAIL
11. ROAD FREIGHT
12. ROAD PASSENGER
13. SHIPPING INLAND FREIGHT
14. SHIPPING INTERNATIONAL FREIGHT
15. MISCELLANEOUS
16. ENERGY INDUSTRY
Various rates of change, e.g.
• efficiency
• energy intensity
• passenger-km
• freight-tonne-km
• household expenditure
• population


Direct combustion/heat
Coal, Gas, Oil
Biofuel, Renewables
Electricity
Coal IGCC & Gas CCGT (with/without CCS)
Renewable, biomass/waste
Existing/new generation nuclear fission
Hydrogen
Gasification
Thermal decomposition
Electrolysis (grid & dedicated)


Test supply meets demand
Calculates:
- carbon intensity
- carbon emissions/sector
- Total UK carbon emissions



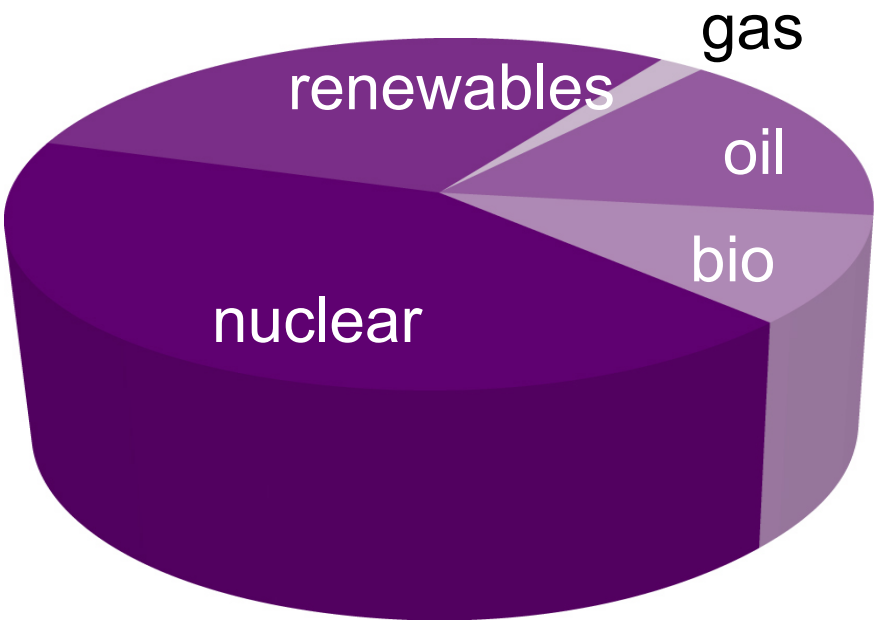
Purple/Pink scenario

Energy demand ~ 330Mtoe
~ 2x today

Hi GDP growth
- some industrial renaissance

Very large mobility increases
- across all modes

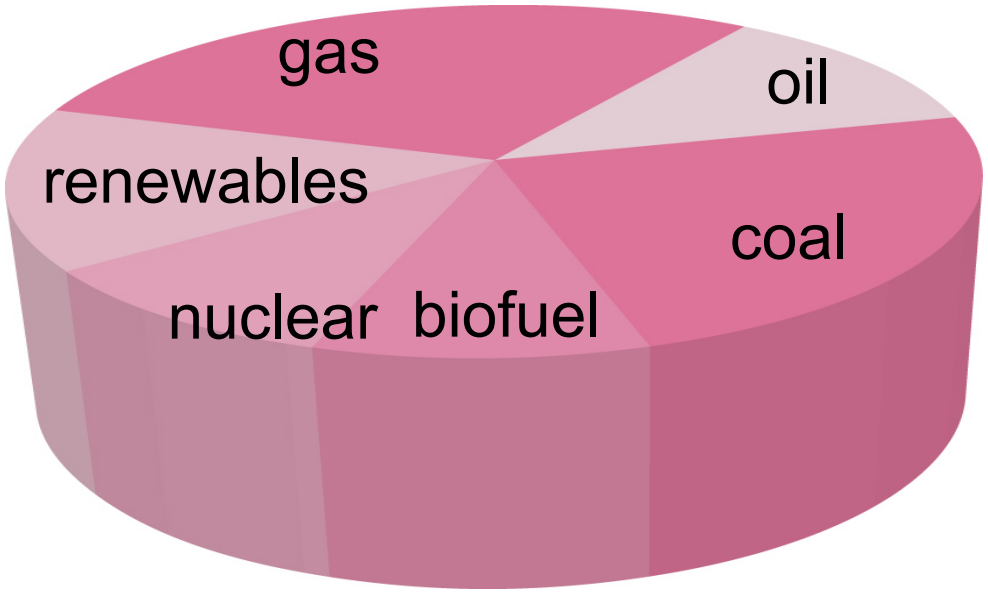
Purple 2050



461 Mtoe

~ 80% electricity

Pink 2050



495 Mtoe

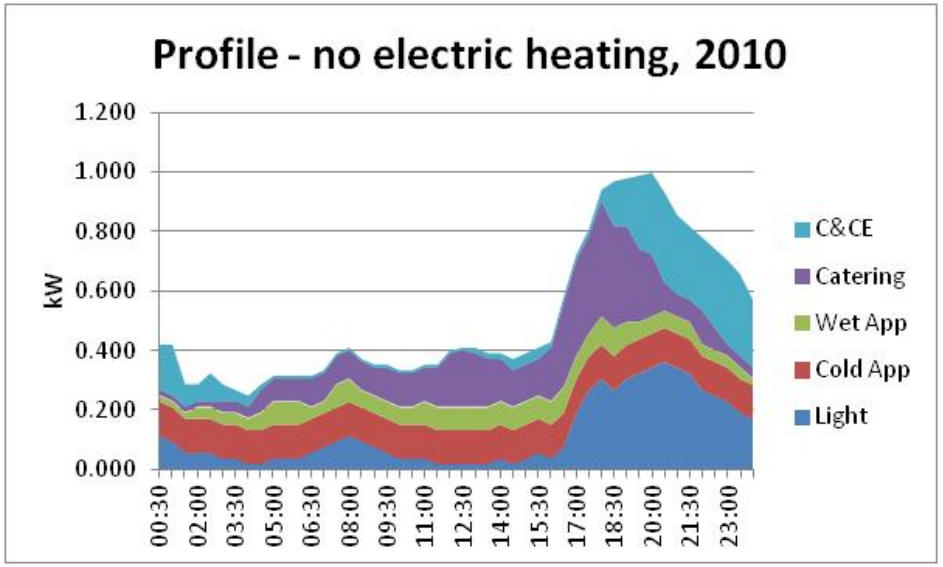
~ 40% electricity

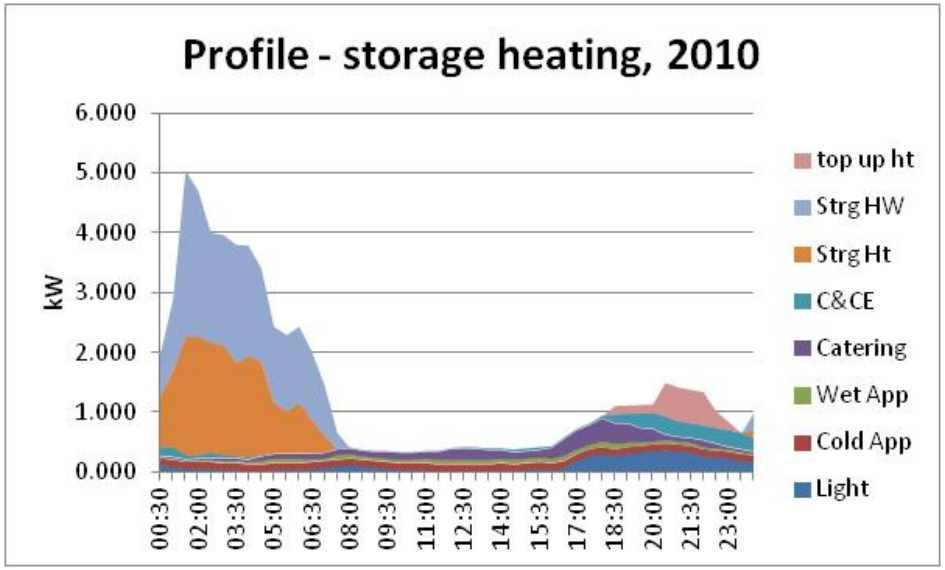
Scenario development: 1 Household's diurnal electricity demand profile

Load profiles, an average house with:

- No electric heating
- Storage heating
- Direct electric heating
- Heat pumps

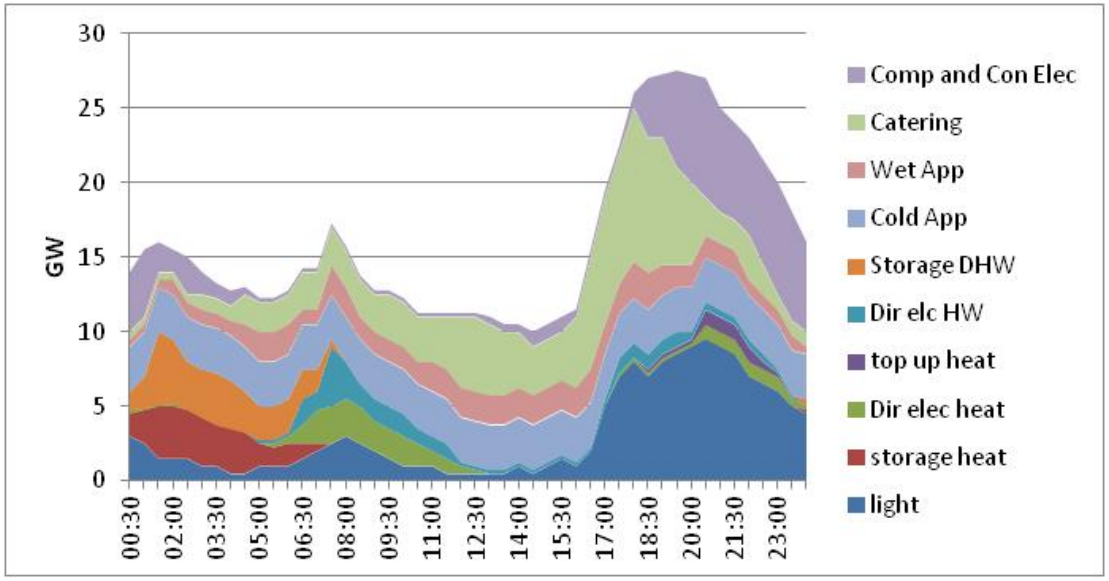
Based on BRE / Exelon data (Not for heat pumps)





Scenario development

Load profiles



1. Develop current load profiles (domestic, non domestic, industry)
2. Sense check against NG data
3. New types of demand (heat pumps, electric cars)
4. Link to sector breakdown – changes in demand, efficiencies etc.
5. Produce new load profiles