

# Using a CAMA approach to model energy efficiency in housing

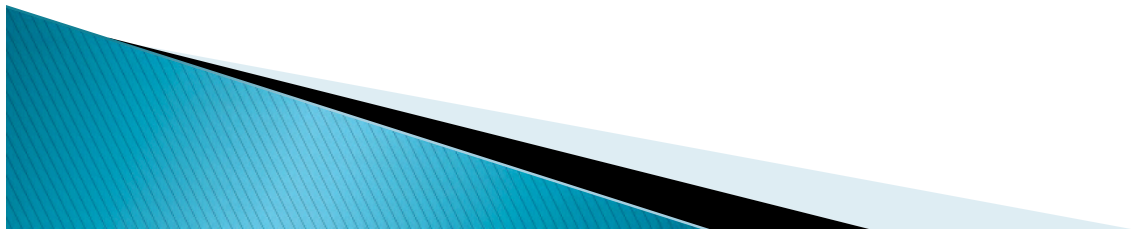
Dr P Davis, Dr W McCluskey, Dr E Montgomery, Dr LC Lim, Dr M McCord, Dr M Haran, Dr D McIlhatton



*18<sup>th</sup> ERES Annual Conference Eindhoven 2011*

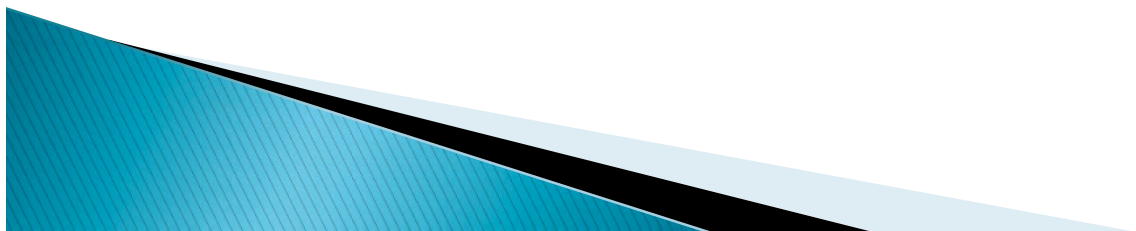
# Background

- ▶ Buildings are responsible for almost 50%
  - of the UK's energy consumption
  - and carbon emissions
- ▶ Even comparatively minor changes
  - in the energy performance of buildings
  - In the way we use each building
  - could have a significant effect
    - energy consumption
    - in reducing carbon emissions



# Background

- ▶ The UK Government supports the Kyoto Protocol
  - This has led to the setting of challenging targets
    - for the reduction of carbon emissions
- ▶ In order to meet these targets
  - Reducing the energy consumption
    - attributable to buildings
    - is a Government key policy objective



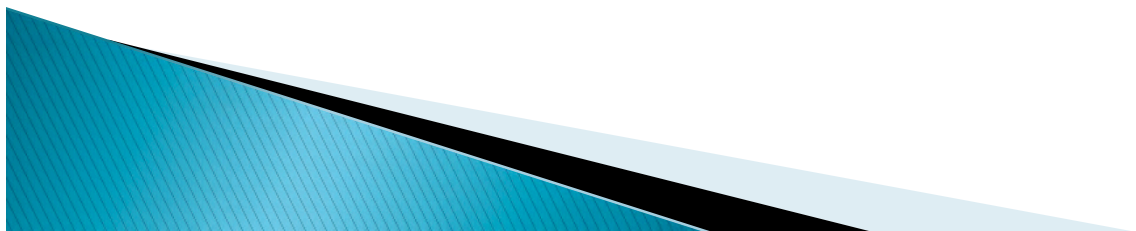
# Background

- ▶ Since 30th December 2008 all properties
  - homes and commercial
  - when constructed or being marketed for sale or rent
  - require an energy performance certificate (EPC)
  - Existing buildings can be assessed under rdSAP 2005 (a simplified assessment process)
- ▶ This initiative is the result of European legislation
  - the Energy Performance of Buildings Directive
  - which all member states were required to adopt



# Background

- ▶ The Department of Finance and Personnel is responsible for measures in Northern Ireland
  - to improve the energy efficiency of buildings, including:
    - energy performance certificates for properties providing A–G efficiency ratings and recommendations for improvement
    - public buildings to display energy certificates
    - inspections for air conditioning systems
    - giving advice and guidance for boiler users



# What affects energy consumption?



- ▶ Housing characteristics
- ▶ User activity
- ▶ Location
- ▶ Climate
- ▶ Etc.
- ▶ Very similar to the housing attributes used to estimate market value
- ▶ At least at a “high level”

# Motivation for our research

- ▶ The quantity of buildings transacting
  - In any time period
  - Is relatively *small*
  - Against the total population
- ▶ EPC lead in time for wide residential coverage
  - Is likely to be considerable
- ▶ Effective asset management of the domestic housing stock
  - Cannot wait for this process to mature!
  - Can some high level research help guide policy and decision making?



# Energy Research

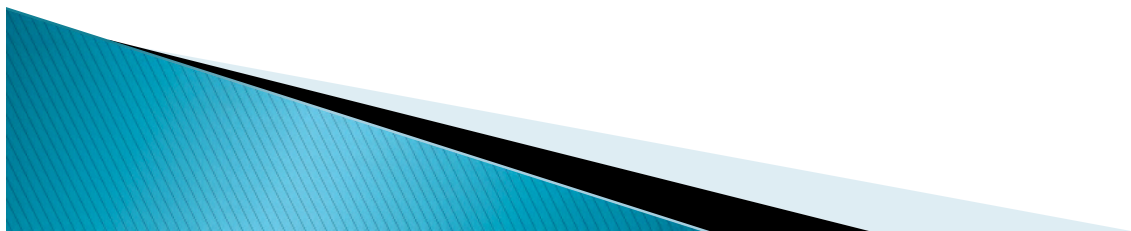
- £20,000 seed funding awarded by EST under the Northern Ireland Project Fund
- To bring together a dataset of property related data
  - 700,000 + property records from LPS (every domestic dwelling in NI)
  - Matched to 300,000 plus property records from EST & NIHE
  - Allowing wide range of research and policy impact analysis
  - Initial project to estimate energy efficiency of NI housing stock, identifying hotspots of poor performance





# Future plan

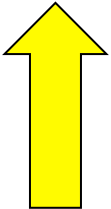
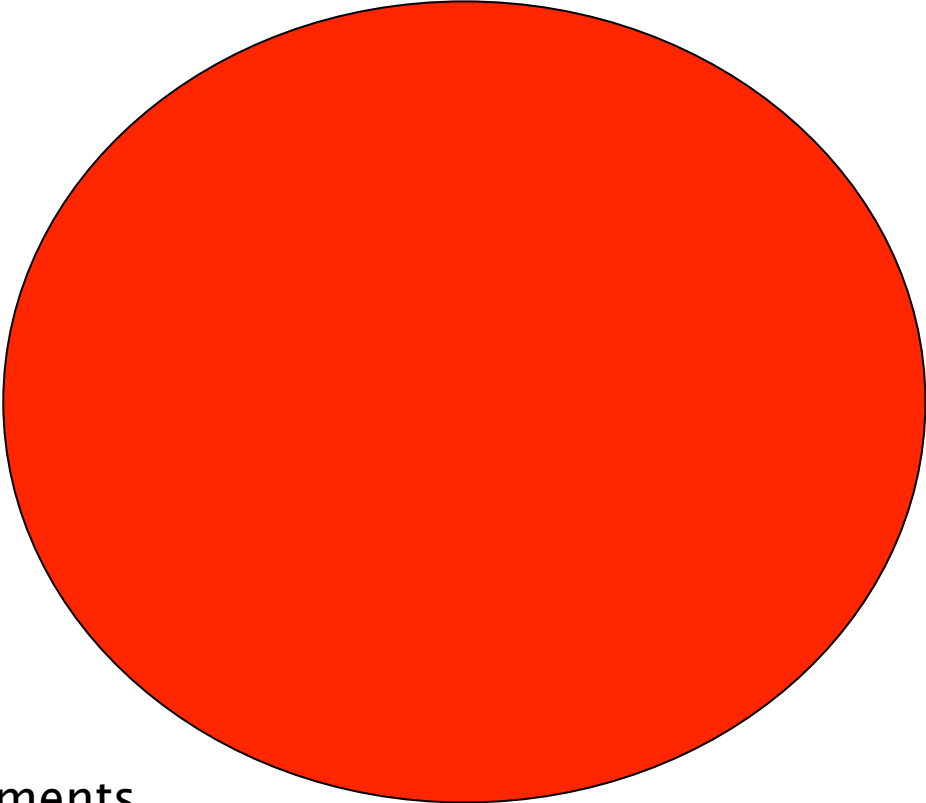
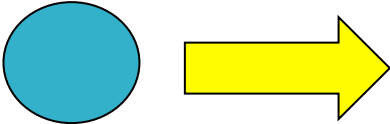
- Subsequent work includes modelling policy options
  - such as extending gas supply
  - analysing effect on value of green features
  - building evidence for evolution and “greening” of property tax policy
- High level support from DFPNI, NIHE and EST
  - has enabled this
  - built on our track record of policy analysis for the DFPNI, DOE and NI Assembly
  - Review of Rating, RPA and Bain Review
- Current status –
  - data now matched, beginning initial analysis
- Expectation of ongoing research output
  - additional funding from future instructions utilising the data set



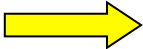
# The Challenge!!

Population

Assessed Sample



Model developed on assessments  
(or calibrated by assessments)

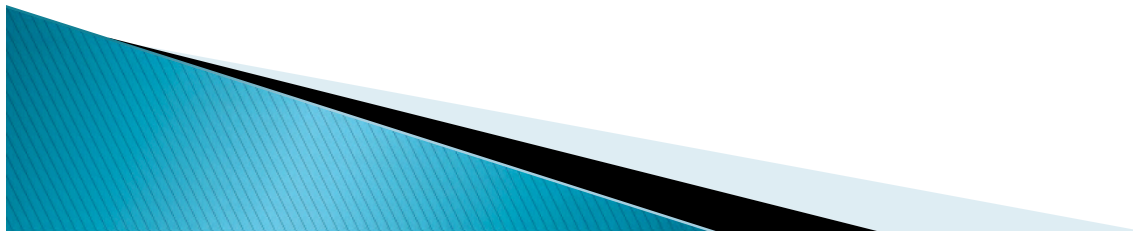


Model applied to all properties



# Initial Modelling

- ▶ Current database contains
  - 710,000 properties
  - 140 property attributes
- ▶ If all fields were completed
  - Full rdSAP 2005 could be calculated
  - For every property in Northern Ireland
- ▶ Unfortunately
  - Life is not that simple!



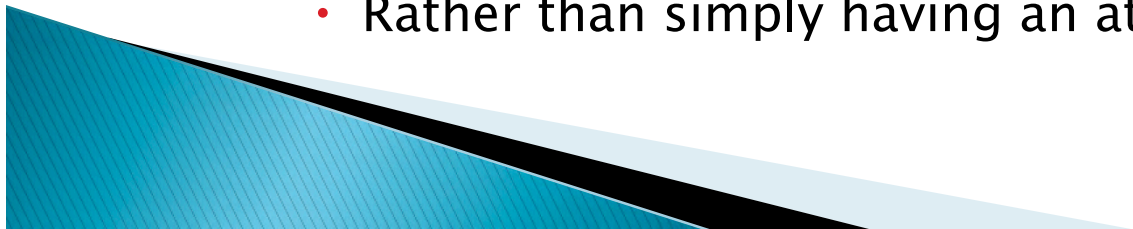
# What have we got?

- ▶ Good quality data from property tax records
  - Addresses, house type/era/size/rooms/assessed value/ etc.
  - Less robust on features such as heating type/ glazing
- ▶ Very “patchy” energy data from EST and other sources
  - Level of insulation/boiler type/heating controls/etc.
- ▶ No clearly identified “summary” variable
  - to become the “dependant”
  - in regression type modelling



# Possible approaches

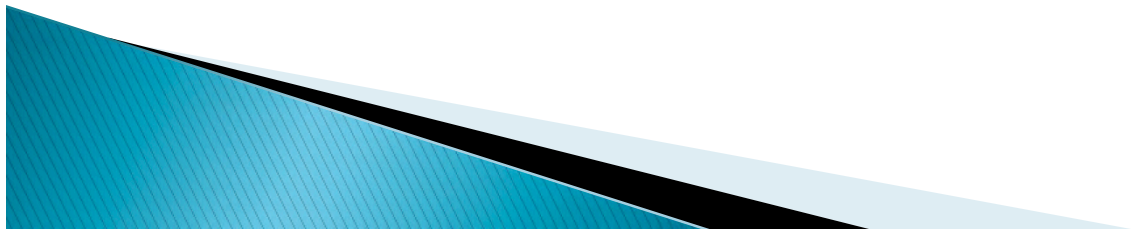
- ▶ Obtain a representative sample
  - of accurate energy estimate figures
  - Such as properties with Energy Performance Certificates
    - EPC's
  - Specifically, the CO<sub>2</sub> kg m<sup>2</sup>pa
    - Which allows a discrete energy figure to be calculated
    - Rather than an allocation to a broad band
    - And allows the impact to be assessed
      - As larger band B properties
      - Will have a higher score
      - Than smaller band B properties
      - Rather than simply having an attribute of “B”



# Planned approach

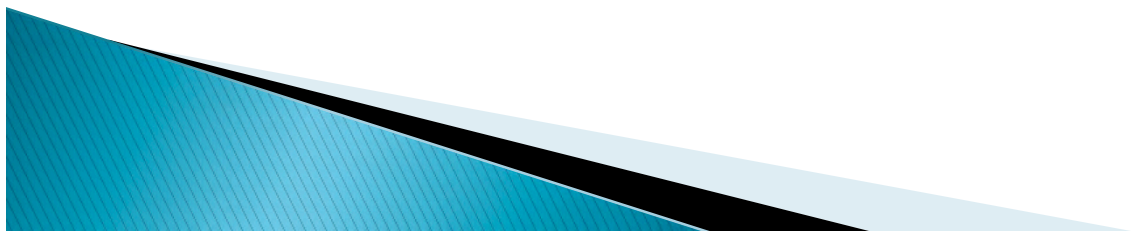
## ▶ Approach 1

- Obtain access to NI EPC database
  - Difficult!
  - One more “pothole” in the road!
  - Success to date gives some hope!
    - Although achieved with considerable “pain”!
  - Enquiries very positive!
- Merge EPC scores with our database
  - Difficult!
  - One *more* pothole in the road!
  - 80%+ match on EST/LPS data achieved gives us hope!



# Planned Approach

- ▶ Use EPC holding properties as the sample
  - Create a discrete energy assessment for each property
    - By multiplying score for CO<sub>2</sub> kg m<sup>2</sup>
    - By actual measured area in m<sup>2</sup> for each property
  - Undertake a range of regression approaches
    - OLS, GWR
  - To estimate the EPC derived energy assessment
    - From the basket of available attributes
    - Limited to those well populated in the population of properties
- ▶ Use the results from the modelling to assess the rest of the properties
  - Following a “Computer Assisted Mass Appraisal” approach



# Caveats

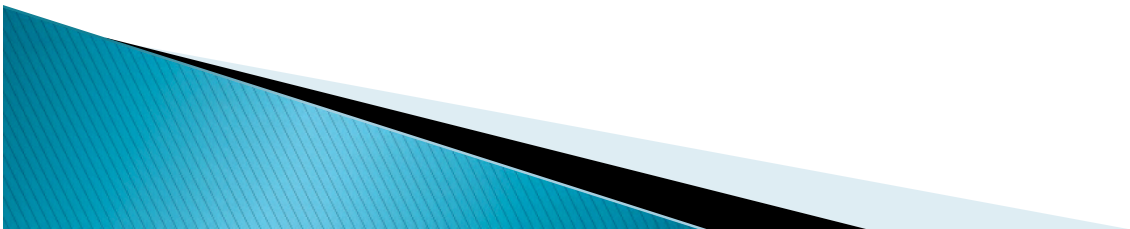
- ▶ The Planned approach has a “timing” related drawback
  - EPC’s only date back to 2008
  - Market has been *very* slow
  - Limiting the *number* of properties with EPC’s for sale purposes
  - Limiting the *geographical range* and *type/age* coverage
- ▶ Rental market has been strong however
  - Improving number of EPC’s available from lettings
  - 8000+ lettings in Belfast Metropolitan Area in 2010
  - See our other paper happening now next door!!
  - All “Warm Home Scheme” affected properties included





# Alternate Approach

- ▶ 2. In the absence of “hard” EPC data
  - Select a representative sample of the properties
  - Utilise industry standard EPC estimation software
    - Eg rdSapper, Elmhurst etc.
  - To “calculate” EPC’s for sample properties
    - Using the data contained in the database
    - Additional enrichment from available sources
    - Some inspections
    - Expert knowledge on typical attribute scores / parameters
    - A range of robust estimations



# Typical EPC rdSAP software

<b>Property details</b> Address line 1 Address line 2 Address line 3 Post Town Post code Built form Detachment Part of UK: England and Wales	<b>Licensed user</b> Evaluation version <b>Assessment details</b> Transaction type Commissioned by Related Party Disclosure Assessment date: 12 June 2011	<b>Dimension type (areas and perimeters)</b> Window areas Whole dwelling window percentages Habitable rooms Report details	<b>Ventilation</b> Mechanical ventilation Number of open fireplaces Electricity meter type Conservatory Percentage of low energy lights Percentage of roof area with PV Terrain Wind turbine Scale water heating																																
<b>Energy efficiency rating</b> <table border="1"> <tr><th>Current</th><th>Enhanced</th></tr> <tr><td>91-100 A</td><td></td></tr> <tr><td>81-90 B</td><td></td></tr> <tr><td>69-80 C</td><td></td></tr> <tr><td>55-68 D</td><td></td></tr> <tr><td>39-54 E</td><td></td></tr> <tr><td>21-38 F</td><td></td></tr> <tr><td>1-20 G</td><td></td></tr> </table>	Current	Enhanced	91-100 A		81-90 B		69-80 C		55-68 D		39-54 E		21-38 F		1-20 G		<b>Environmental (CO<sub>2</sub>) Impact Rating</b> <table border="1"> <tr><th>Current</th><th>Enhanced</th></tr> <tr><td>91-100 A</td><td></td></tr> <tr><td>81-90 B</td><td></td></tr> <tr><td>69-80 C</td><td></td></tr> <tr><td>55-68 D</td><td></td></tr> <tr><td>39-54 E</td><td></td></tr> <tr><td>21-38 F</td><td></td></tr> <tr><td>1-20 G</td><td></td></tr> </table>	Current	Enhanced	91-100 A		81-90 B		69-80 C		55-68 D		39-54 E		21-38 F		1-20 G		Start Data input wizard Report details	Next Previous Apply
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<b>Room in roof (main part of dwelling)</b> Construction date Floor area (sq m) Insulation	<b>Alternative Wall</b> Location Area (sq m) Wall construction Insulation	<b>Select type of main heating</b> wet system with radiators or underfloor electric storage system warm air system room heater system community heating community heating with CHP or heat exchanger electric underfloor heating other system	<b>Adjusted efficiency</b> 0%																																
<b>Main dwelling age and construction</b> Age of main dwelling Roof type External wall type Floor type Roof insulation Wall insulation Floor insulation	<b>Dimensions</b> <table border="1"> <thead> <tr> <th></th> <th>Area (sq m)</th> <th>H (m)</th> <th>Exposed perimeter</th> </tr> </thead> <tbody> <tr><td>Lowest floor + 6</td><td></td><td></td><td></td></tr> <tr><td>Lowest floor + 5</td><td></td><td></td><td></td></tr> <tr><td>Lowest floor + 4</td><td></td><td></td><td></td></tr> <tr><td>Lowest floor + 3</td><td></td><td></td><td></td></tr> <tr><td>Lowest floor + 2</td><td></td><td></td><td></td></tr> <tr><td>Lowest floor + 1</td><td></td><td></td><td></td></tr> <tr><td>Ground floor</td><td></td><td></td><td></td></tr> </tbody> </table>		Area (sq m)	H (m)	Exposed perimeter	Lowest floor + 6				Lowest floor + 5				Lowest floor + 4				Lowest floor + 3				Lowest floor + 2				Lowest floor + 1				Ground floor				Select boiler type Type of fuel Extension details Next Previous Apply	Next Previous OK
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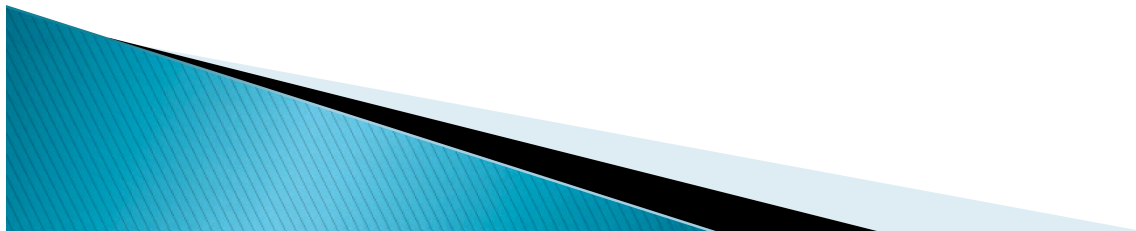
# Alternate Approach

- ▶ Once the EPC scores have been derived for the sample
  - The process of modelling reverts to the planned approach
    - Regression analysis
    - Application to the entire data set
- ▶ Limitations
  - Accuracy of EPC estimation
    - In this type of exercise
  - Time cost
    - To find, check, fill etc.



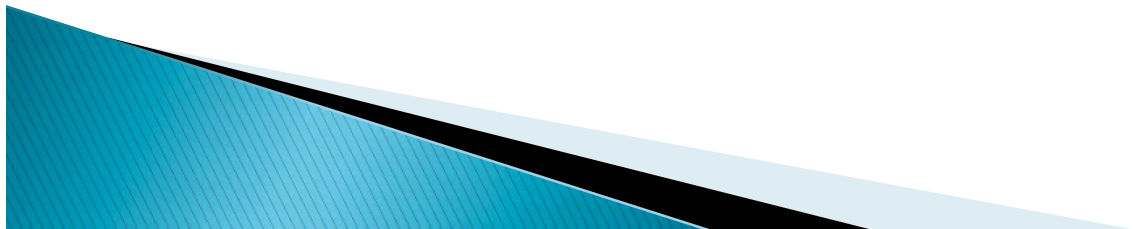
# Initial Exploratory Approach

- ▶ Initial “robust” modelling has been undertaken
  - To “test the water”
  - And demonstrate the analytic and explanatory power
    - of the underlying dataset
  - To help identify the potential of the project
    - To augment policy development



# Exploratory Approach

- ▶ The initial modelling exercise
  - Identifies a set of 30 “typologies”
  - Within which each property in the data set is placed
- ▶ Exclusions
  - Usual data cleaning was carried out
    - To remove outliers which are poorly represented
    - Or *appear* to be faulty
      - Such as “Castle”
      - floor are  $>400 \text{ m}^2$
      - Floor area  $<40 \text{ m}^2$
    - Removing flats/apartments
      - Worst affected by current data match
      - However probably well represented in EPC terms
      - Will be included as research develops



# Typologies

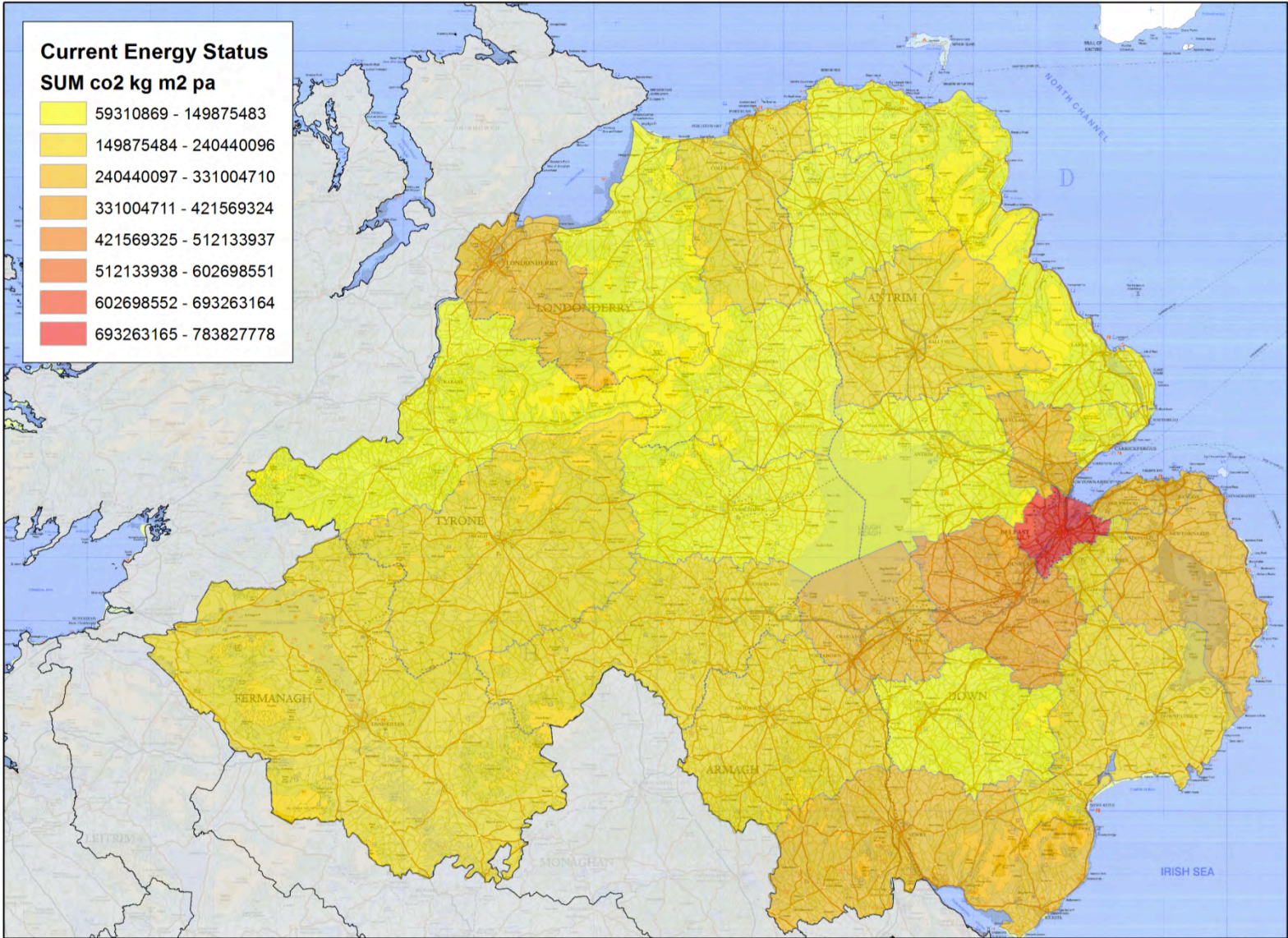
- ▶ 30 Property Typologies devised
  - Driven by categories on the LPS (Property Tax) data
- ▶ 6 Property “type” categories
  - Detached House
  - Semi Detached House
  - Terraced House
  - Detached Bungalow
  - Semi Detached Bungalow
  - Terraced Bungalow
    - (very few!)
- ▶ 5 age band categories
  - From pre 1919 to present day
- ▶ 6 times 5 = 30!



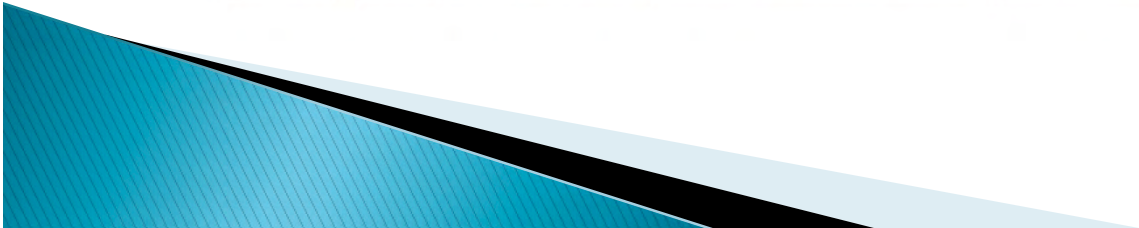
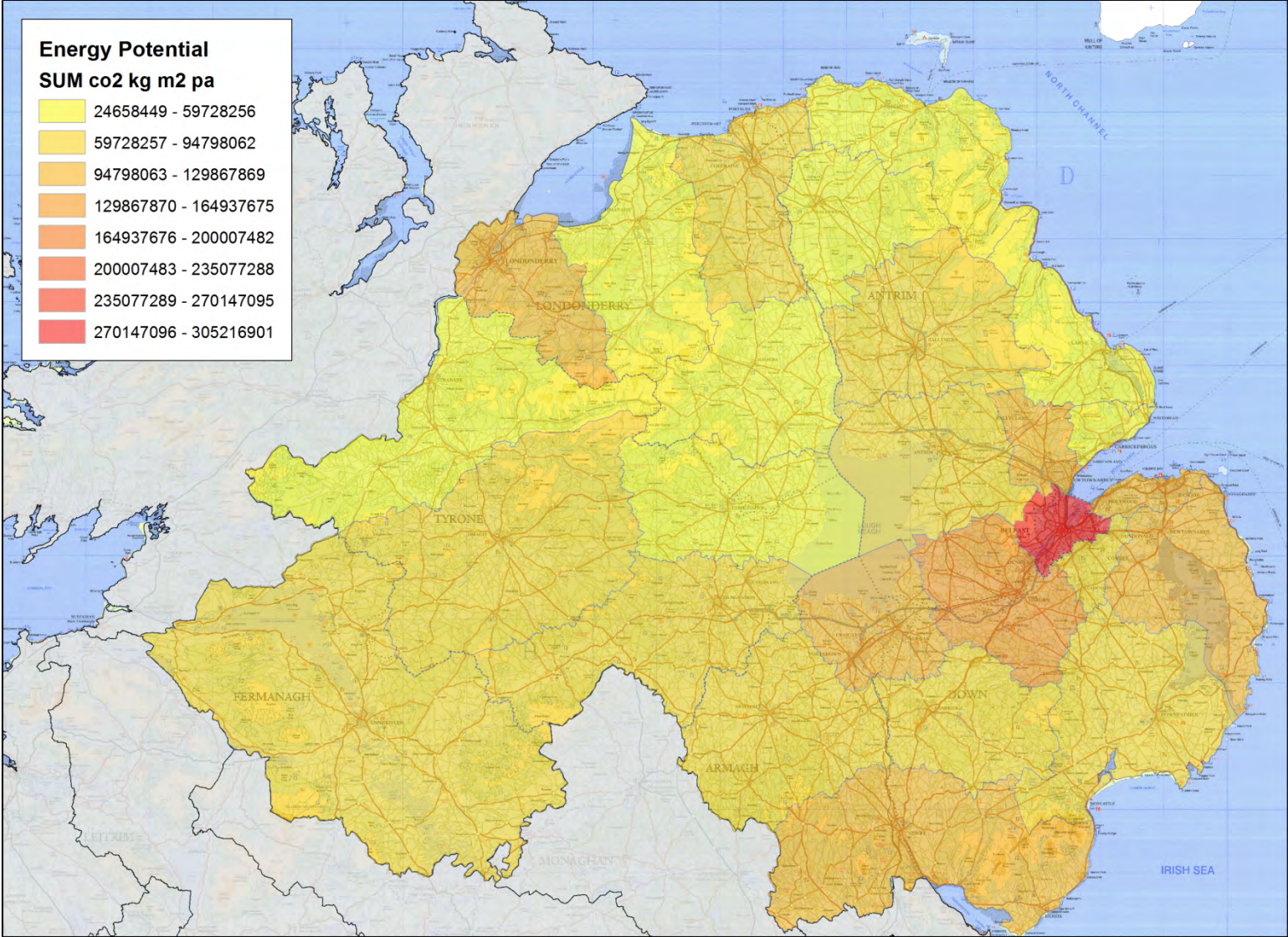
# Energy score

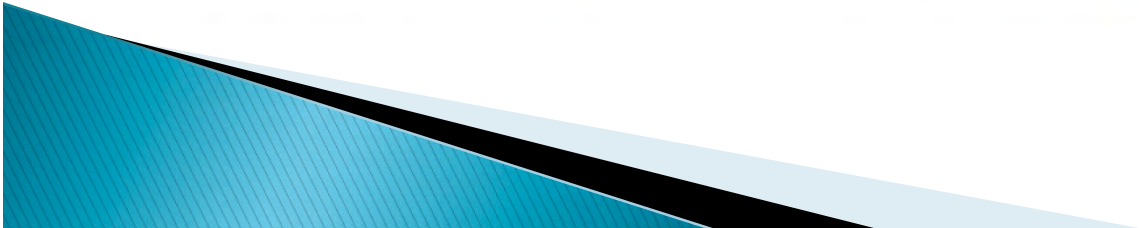
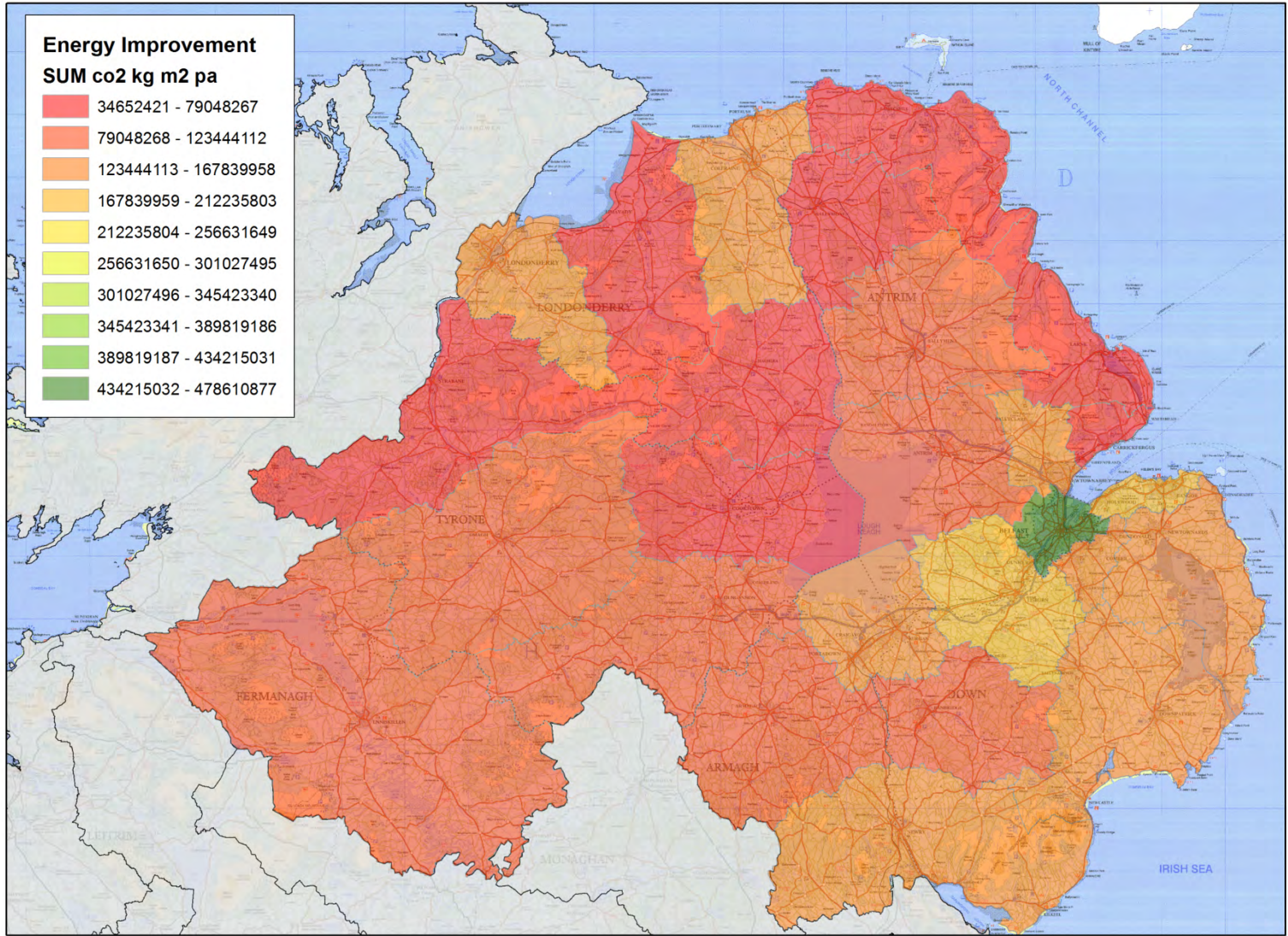
- ▶ A variety of data sources have been considered
- ▶ To estimate a robust CO<sub>2</sub> Kg m<sup>2</sup> pa figure
  - for each typology
  - in its deemed “average” condition
  - In its deemed “best cost effective improved” condition
- ▶ These figures are then applied
  - To the floor area data
  - To create a discrete CO<sub>2</sub> Kg m<sup>2</sup> pa “before” and “after” figure
  - for each property in the database
- ▶ Whilst fairly “rough and ready”
  - It does calculation of a “reasonable” level of “relative performance”
  - And potential gain in performance on improvement
  - To be calculated and mapped





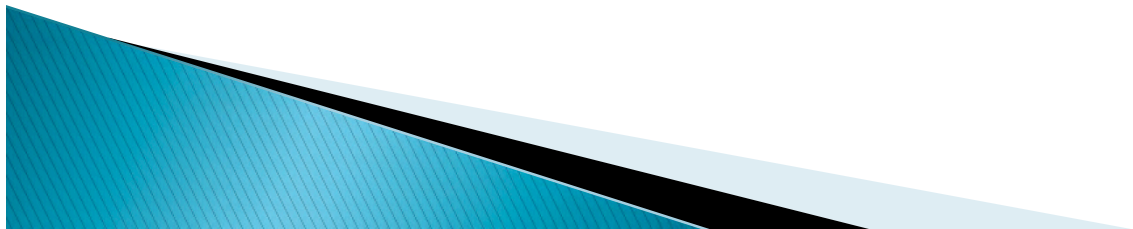


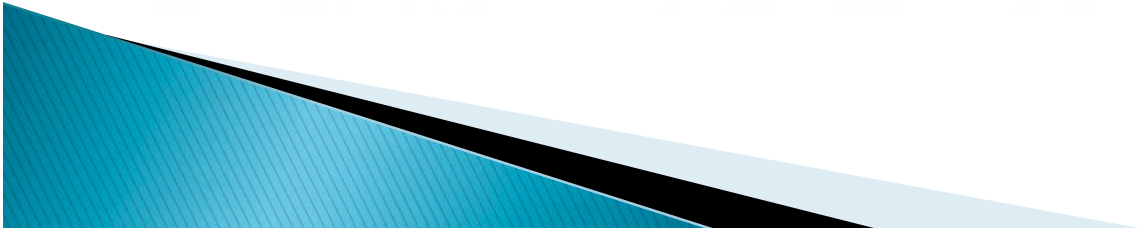


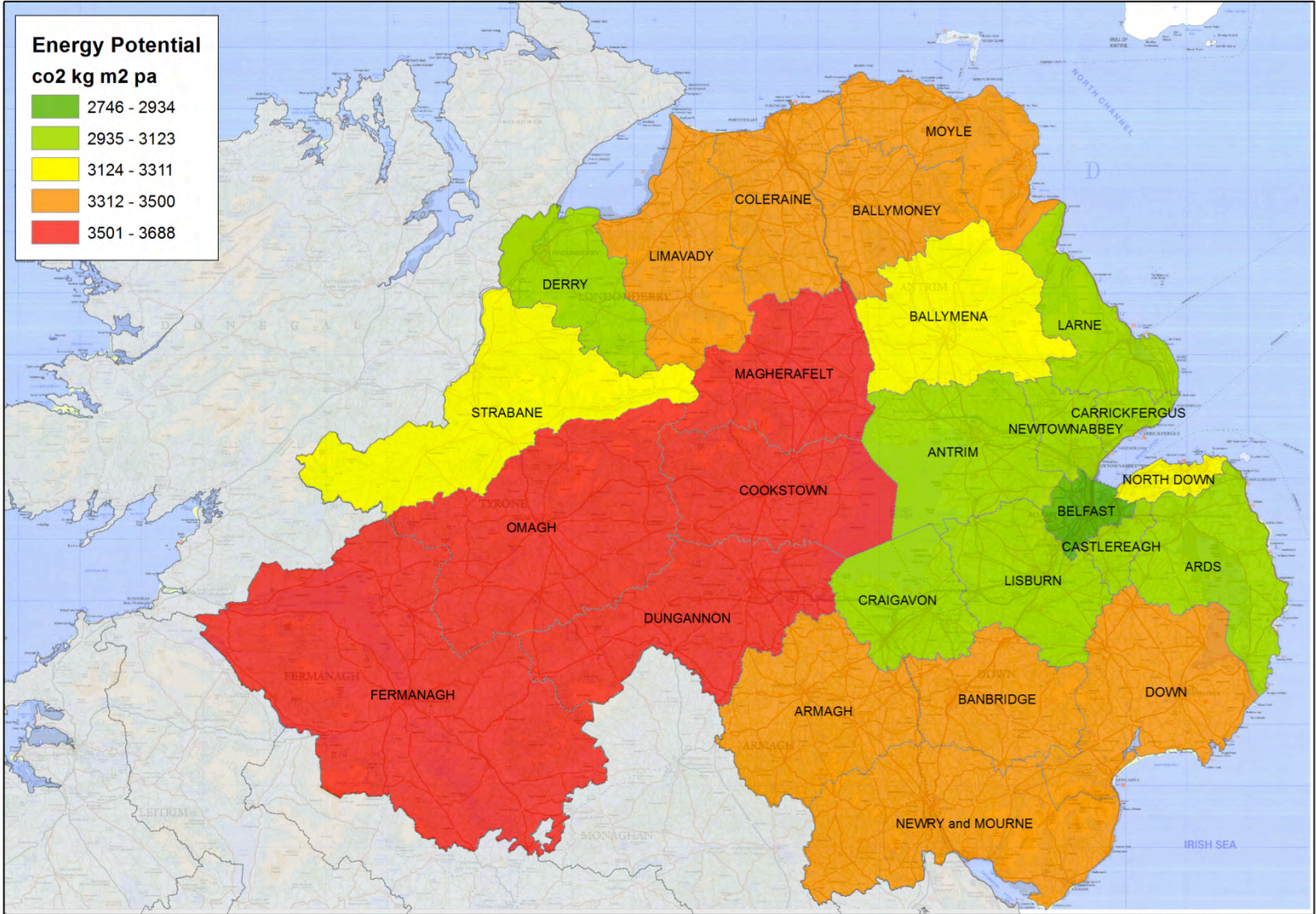


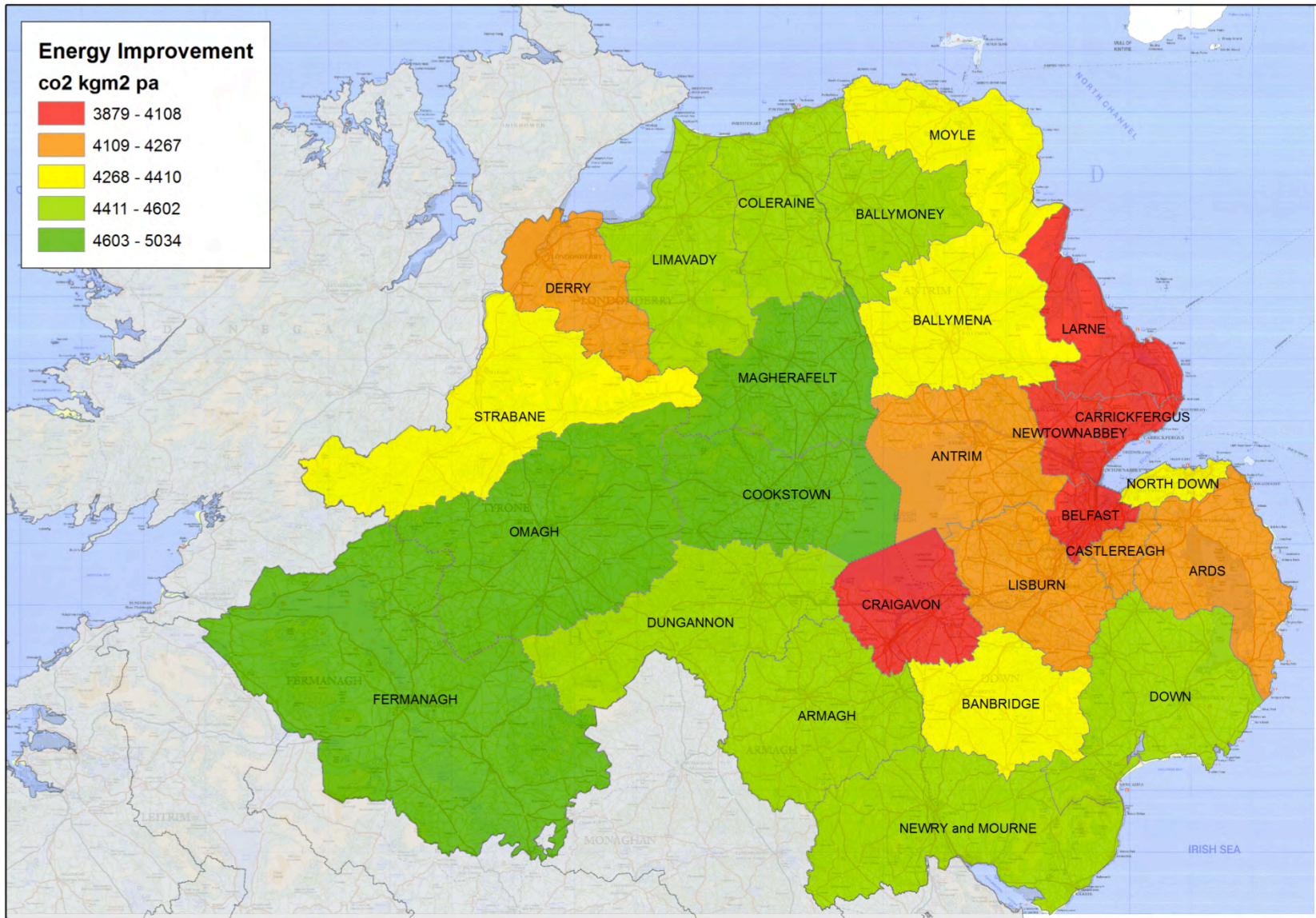
# Overall level analysis

- ▶ Analysis of the overall level analysis
  - Indicates large “heat Island” effect of urban areas
    - Reflecting the density of development
    - And density of energy consumption
  - Indications are that at this level of analysis
    - Most benefit can be gained by improving performance
    - Of property in urban areas
      - Notably Belfast!



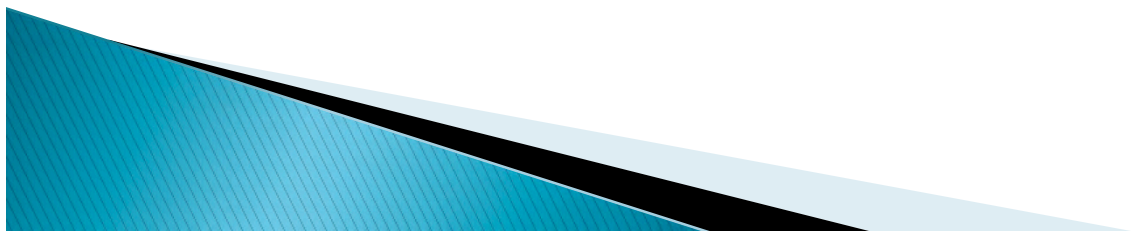


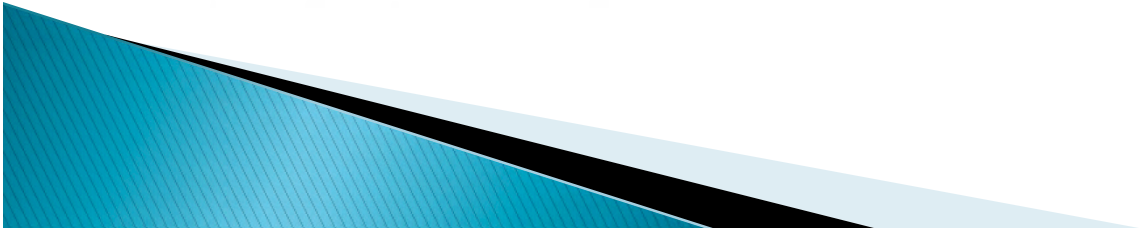
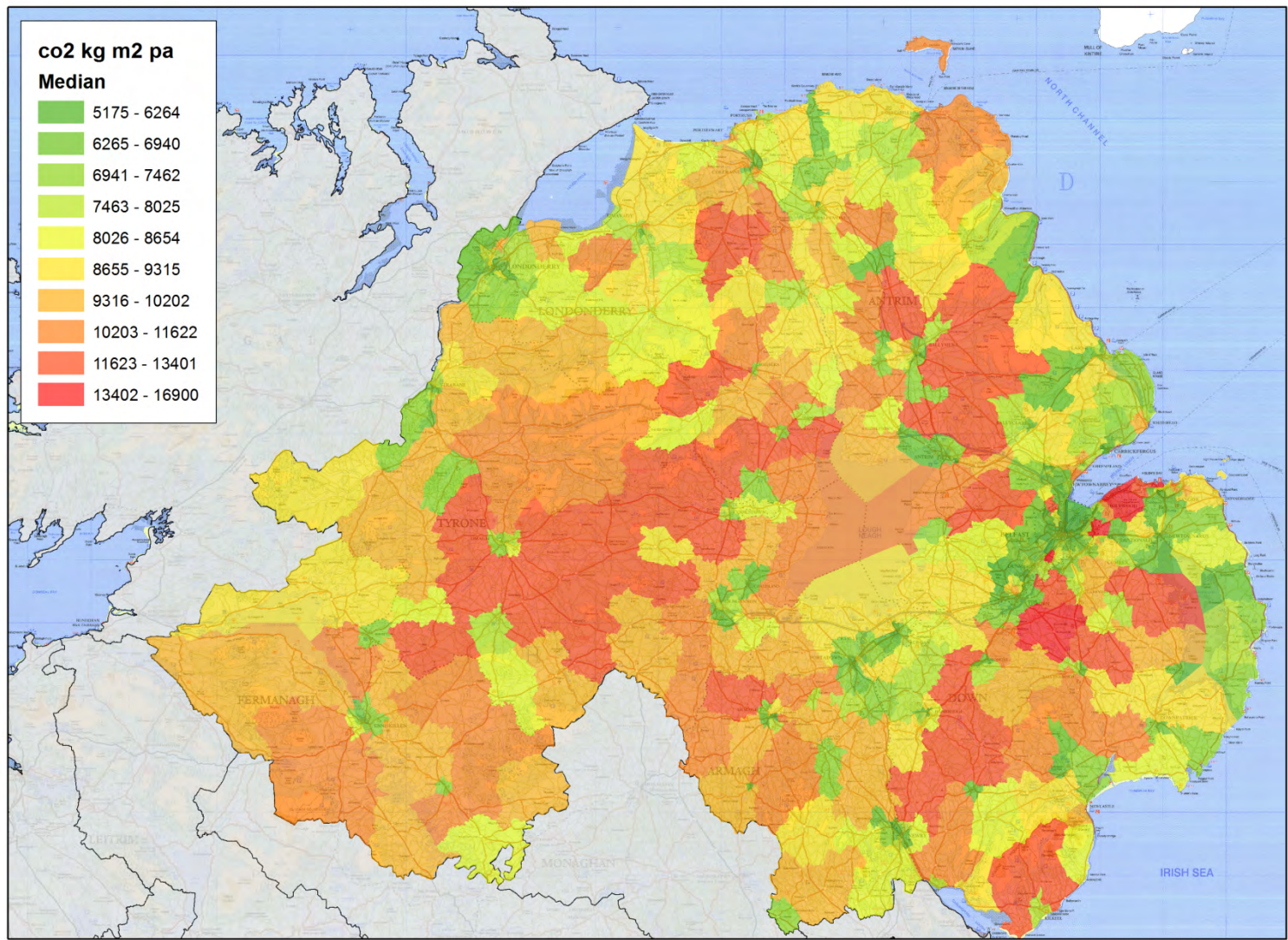




# Median level analysis

- ▶ Median level analysis
  - Teases out a different story
    - On average, urban properties are “greener”
    - Rural areas suffering from “Bungalowification” effect!!!
  - Indications are that at this level of analysis
    - On a case by case basis
      - Most benefit can be gained by improving performance
  - Of property in rural areas Clearly identifies a difference between
    - *Areas* which consume a lot of energy
    - *Areas with properties* that consume a lot of energy

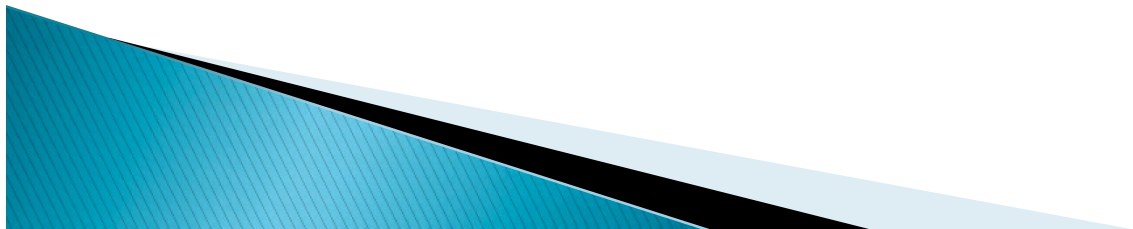






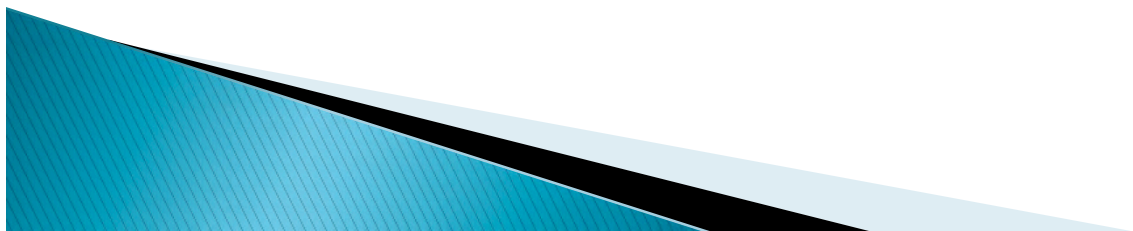
# Initial findings

- ▶ Drilling down into a Ward Level analysis
- ▶ Overall pattern less clear
  - Urban areas still do better
  - “patchwork quilt” effect!
- ▶ Identifies urban areas
  - Good, average, bad
- ▶ Identifies rural areas
  - Good, average, bad
- ▶ Harder to generalise – good for targeting!



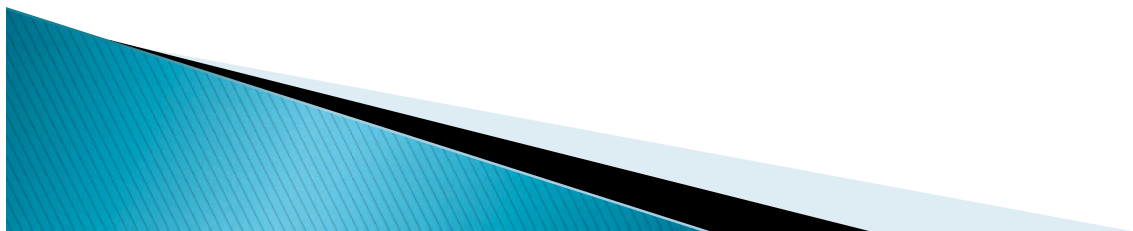
# Initial outcomes

- The emerging findings suggest the data
  - Can provide useful “high level” intelligence
  - About the geographical dispersion of energy efficiency
  - Potential to identify key locales where there is
    - More of a problem
    - More to gain
- Improving the rigour of the modelling will hopefully augment
  - predictive accuracy
  - Analytic power



# Practical application

- This could be useful in a variety of ways
  - targeting advertising of energy schemes
  - In selecting *mode* for example
    - TV/Radio/Newspaper in Urban areas (more to cover)?
    - Targeted mail shot to rural (More to gain)?
    - Obvious? Perhaps – but here is some evidence!
  - Tailoring *message* to appropriate user groups
    - User behaviour message
      - where performance of stock good
    - Asset improvement message
      - Where performance of stock weak
- Improving knowledge of the stock to facilitate
  - Greening of property tax
  - “Green Deal”



▶ Thank You for  
Listening!!

