Life-Cycle Assessment of Greenhouse Gas Emissions from Shale Gas Extraction in Scotland

Clare Bond, University of Aberdeen

clare.bond@abdn.ac.uk

Life Cycle Assessment of Shale Gas in Scotland

climate change Scotland's centre of expertise connecting climate change research and policy

Life-Cycle Assessment of Greenhouse Gas Emissions from Unconventional Gas in Scotland

Main Report, August 2014

Bond C.E.[1], Roberts J.[2], Hastings A.[3], Shipton Z.K.[2], João E.M.[2], Tabyldy Kyzy J.[1], Stephenson M.[4]

1. University of Aberdeen, School of Geosciences Science
2. University of Strathclyde, Department of Civil and Environmental Engineering
3. University of Aberdeen, School of Biological Science
4. British Geological Survey

Citation

Bond C.E., Roberts J., Hastings A., Shipton Z.K., João E.M., Tabyldy Kyzy J., Stephenson M. 2014 Life-cycle assessment of greenhouse gas emissions from unconventional gas in Scotland. A ClimateXChange Report, Scotland, http://www.climatexchange.org.uk/reducing-emissions/understanding-potential-climate-impact-unconventional-gas-extraction-scotland

Life-Cycle Assessment of Greenhouse Gas Emissions from Unconventional Gas Extraction in Scotland

Bond C.E.[1], Roberts J.[2], Hastings A.[1], Shipton Z.K.[2], João E.M.[2], Tabyldy Kyzy J.[1], Stephenson M.[3]

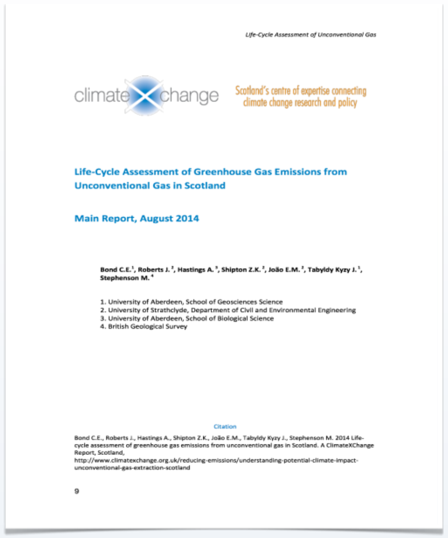
1. University of Aberdeen; 2. University of Strathclyde; 3. British Geological Survey

Available online:

http://www.climatexchange.org.uk

clare.bond@abdn.ac.uk

Life Cycle Assessment of Shale Gas in Scotland


Life-Cycle Assessment of Unconventional Gas

climate change — Scotland's centre of expertise connecting climate change research and policy

Life-Cycle Assessment of Greenhouse Gas Emissions from Unconventional Gas in Scotland

Main Report, August 2014

Bond C.E.[1], Roberts J.[2], Hastings A.[3], Shipton Z.K.[2], João E.M.[2], Tabyldy Kyzy J.[1], Stephenson M.[4]

1. University of Aberdeen, School of Geosciences Science
2. University of Strathclyde, Department of Civil and Environmental Engineering
3. University of Aberdeen, School of Biological Science
4. British Geological Survey

Citation

Bond C.E., Roberts J., Hastings A., Shipton Z.K., João E.M., Tabyldy Kyzy J., Stephenson M. 2014 Life-cycle assessment of greenhouse gas emissions from unconventional gas in Scotland. A ClimateXChange Report, Scotland, http://www.climatexchange.org.uk/reducing-emissions/understanding-potential-climate-impact-unconventional-gas-extraction-scotland

9

Commissioned report

SEPA (2012) regulatory guidance on CBM & shale gas identified:

- A lack of real field data on greenhouse gas emissions
- Different assertions of fugitive emissions of methane
- Climate impact of unconventional gas = uncertain.

Requested this (desk-based) LCA in order to-

- Establish the **current information** base
- Assess how much the potential GHG emissions may vary due to **Scottish context** and different techniques and practices
- Identify where regulation could significantly lower emissions

clare.bond@abdn.ac.uk

Life Cycle Assessment of Shale Gas in Scotland

Life-Cycle Assessment of Unconventional Gas

climateXchange Scotland's centre of expertise connecting climate change research and policy

Life-Cycle Assessment of Greenhouse Gas Emissions from Unconventional Gas in Scotland

Main Report, August 2014

Bond C.E.[1], Roberts J.[2], Hastings A.[3], Shipton Z.K.[2], João E.M.[2], Tabyldy Kyzy J.[1], Stephenson M.[4]

1. University of Aberdeen, School of Geosciences Science
2. University of Strathclyde, Department of Civil and Environmental Engineering
3. University of Aberdeen, School of Biological Science
4. British Geological Survey

Citation

Bond C.E., Roberts J., Hastings A., Shipton Z.K., João E.M., Tabyldy Kyzy J., Stephenson M. 2014 Life-cycle assessment of greenhouse gas emissions from unconventional gas in Scotland. A ClimateXChange Report, Scotland, http://www.climatexchange.org.uk/reducing-emissions/understanding-potential-climate-impact-unconventional-gas-extraction-scotland

9

Department of Energy & Climate Change

Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use

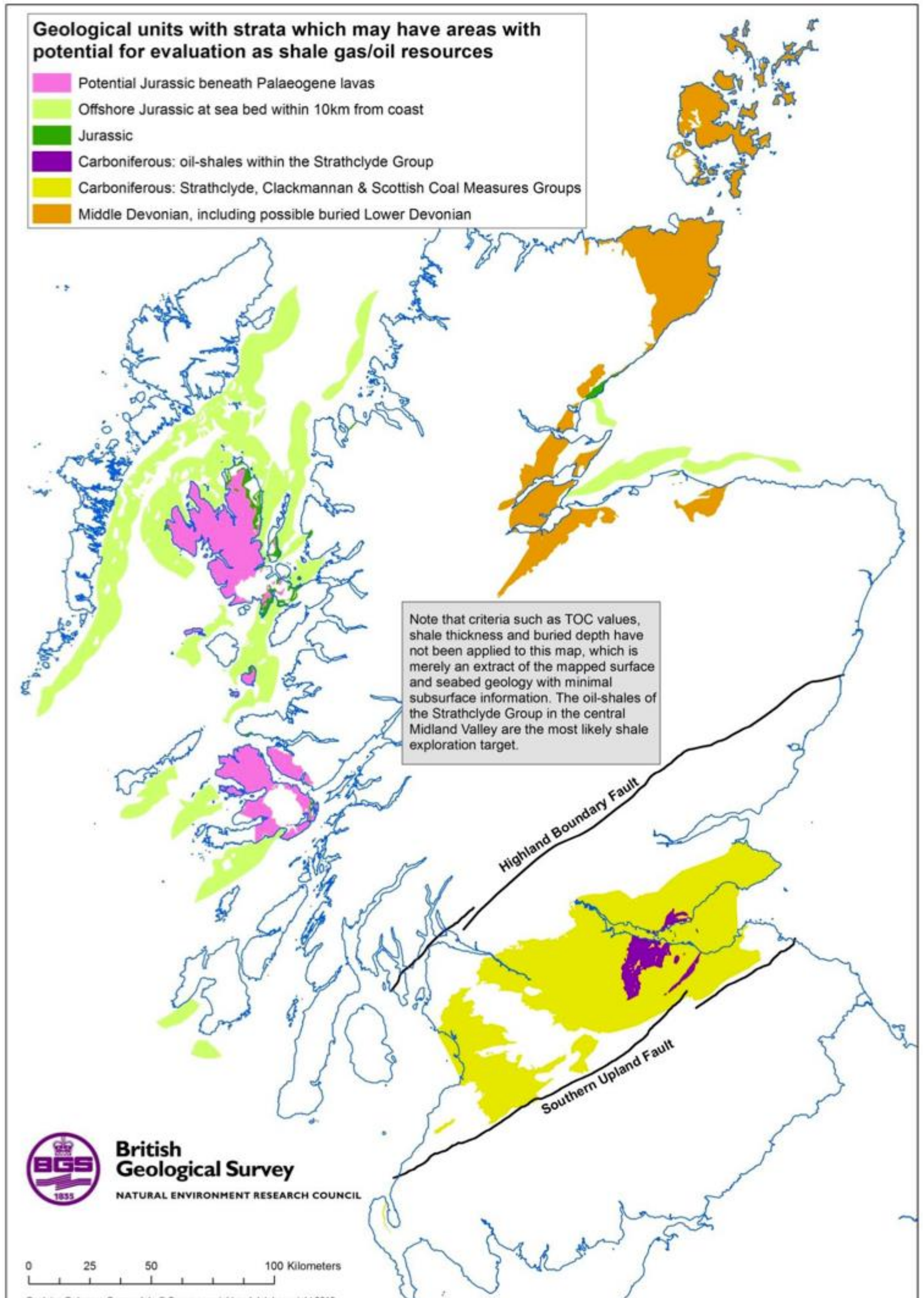
Professor David J C MacKay FRS

Dr Timothy J Stone CBE

9th September 2013

clare.bond@abdn.ac.uk

The Scottish Shale Resource: Gas and Oil



BGS-DECC 2014 reports

Midland Valley - Scotland

- Shale **gas** estimate: 49.4 - 134.6 **tcf**
- Shale **oil** estimate: 3.2 - 11.2 **bbl**

Bowland Shale – England

- Shale **gas** estimate: 822 - 2281 **tcf**

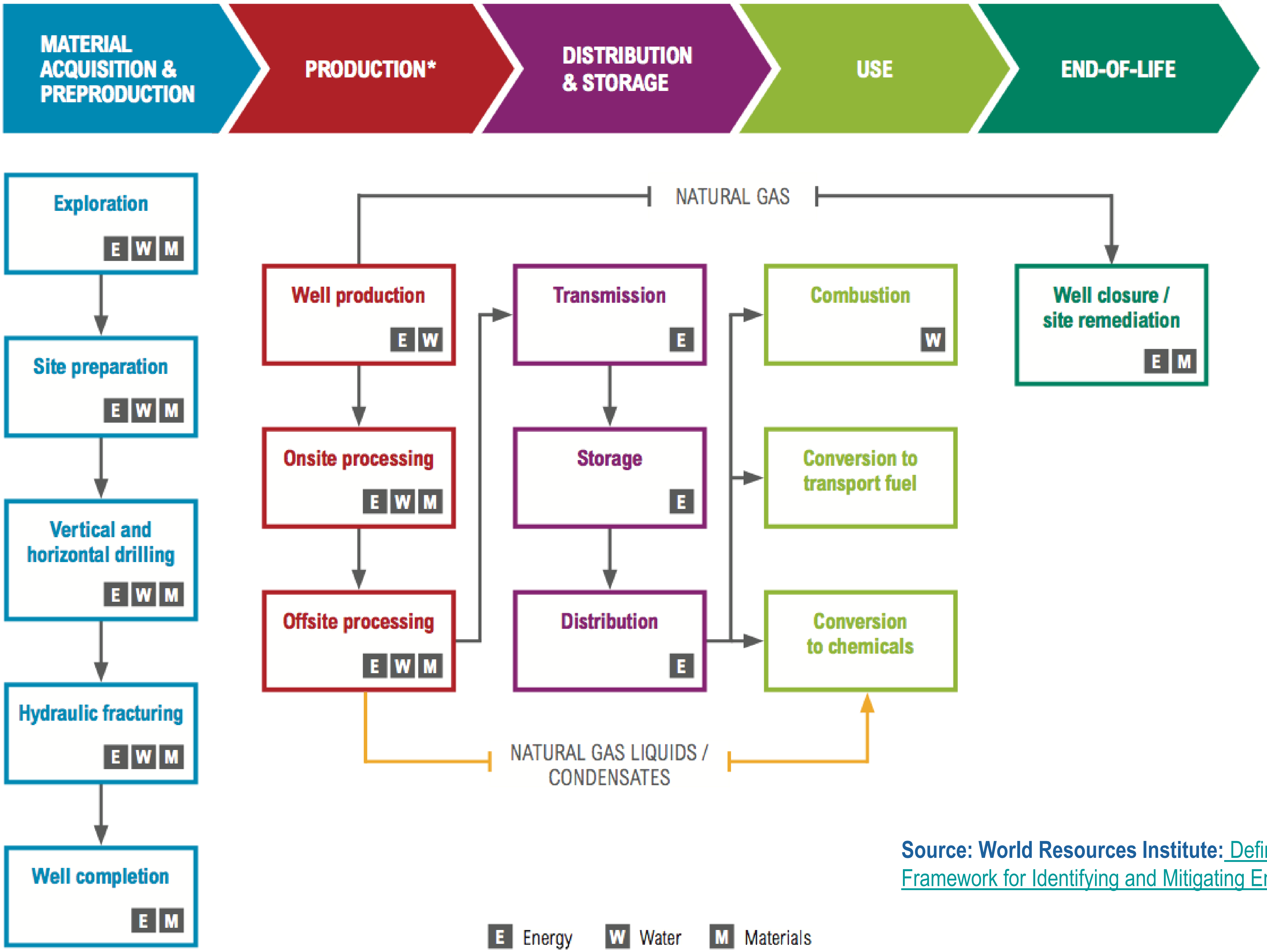
Weald Basin – England

- Shale **oil** estimate: 2.20 - 8.57 **bbl**

Source: Scottish Government, 2014 Report on Unconventional Oil And Gas (Independent Expert Scientific Panel)

clare.bond@abdn.ac.uk

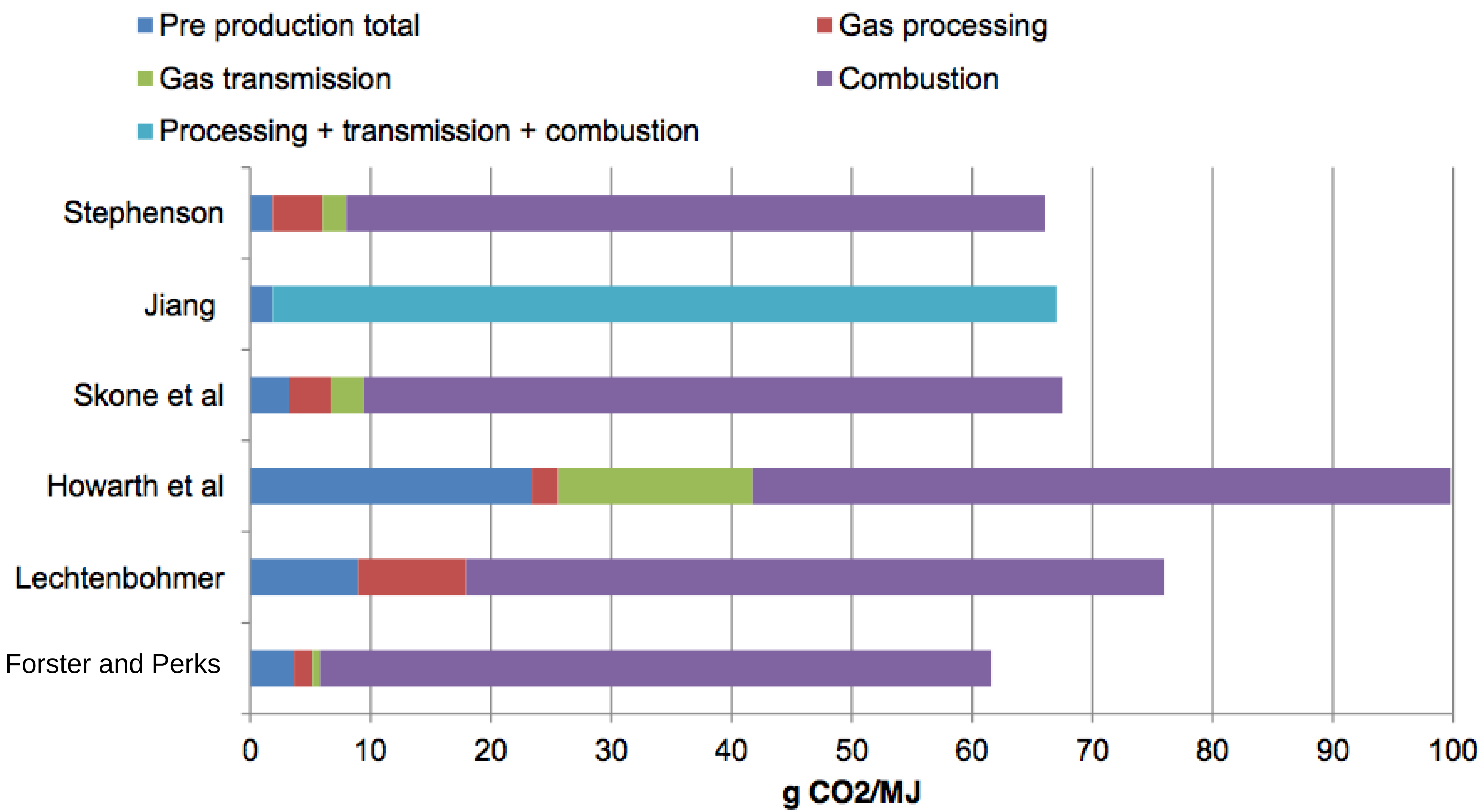
Life Cycle Assessment of Shale Gas: Boundaries



Source: World Resources Institute: Defining the Shale Gas Life Cycle: A Framework for Identifying and Mitigating Environmental Impacts (2012).

clare.bond@abdn.ac.uk

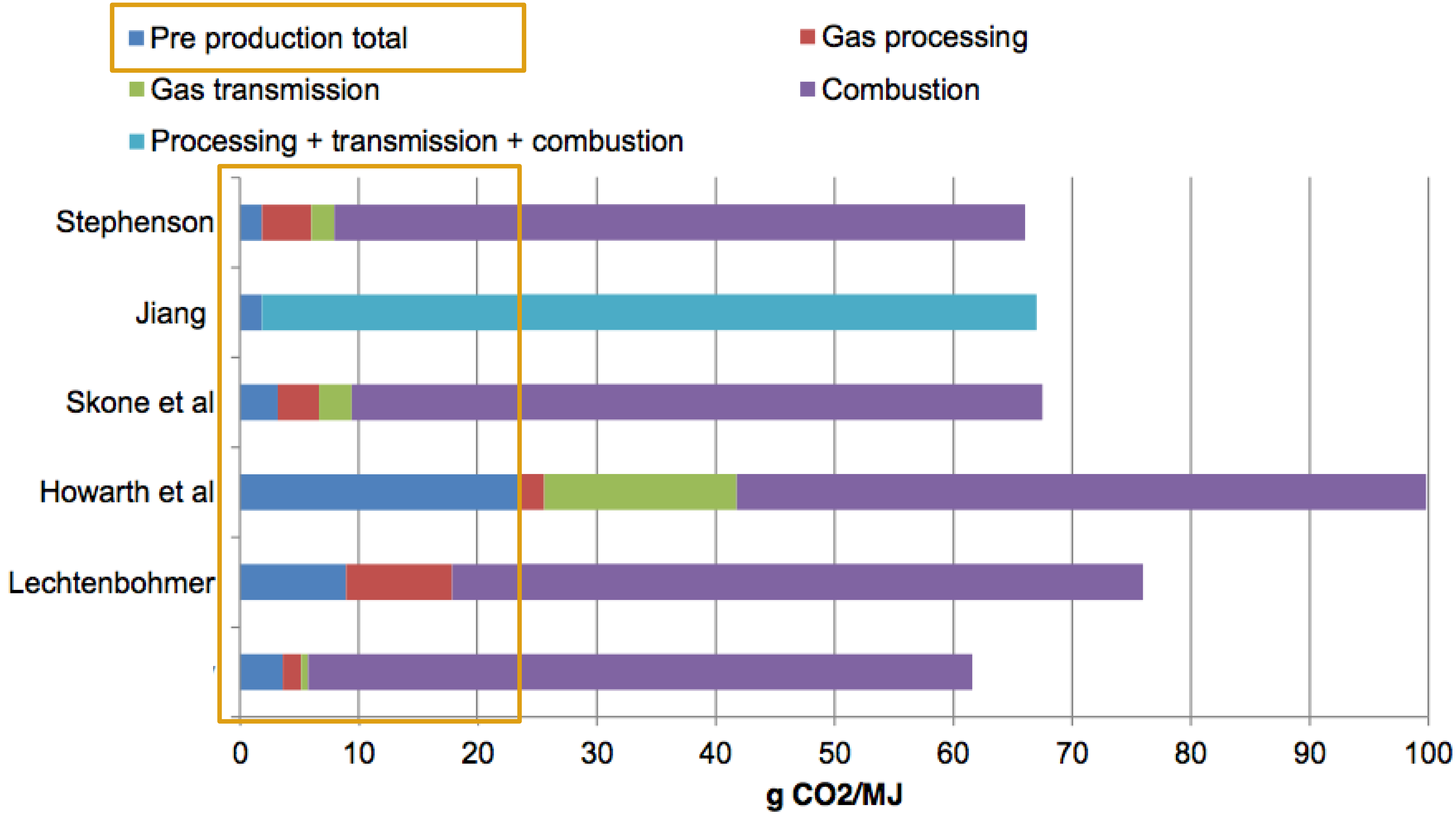
Previous LCAs: Comparison of results



Source: AEA (2012) Climate impact of potential shale gas production in the EU

clare.bond@abdn.ac.uk

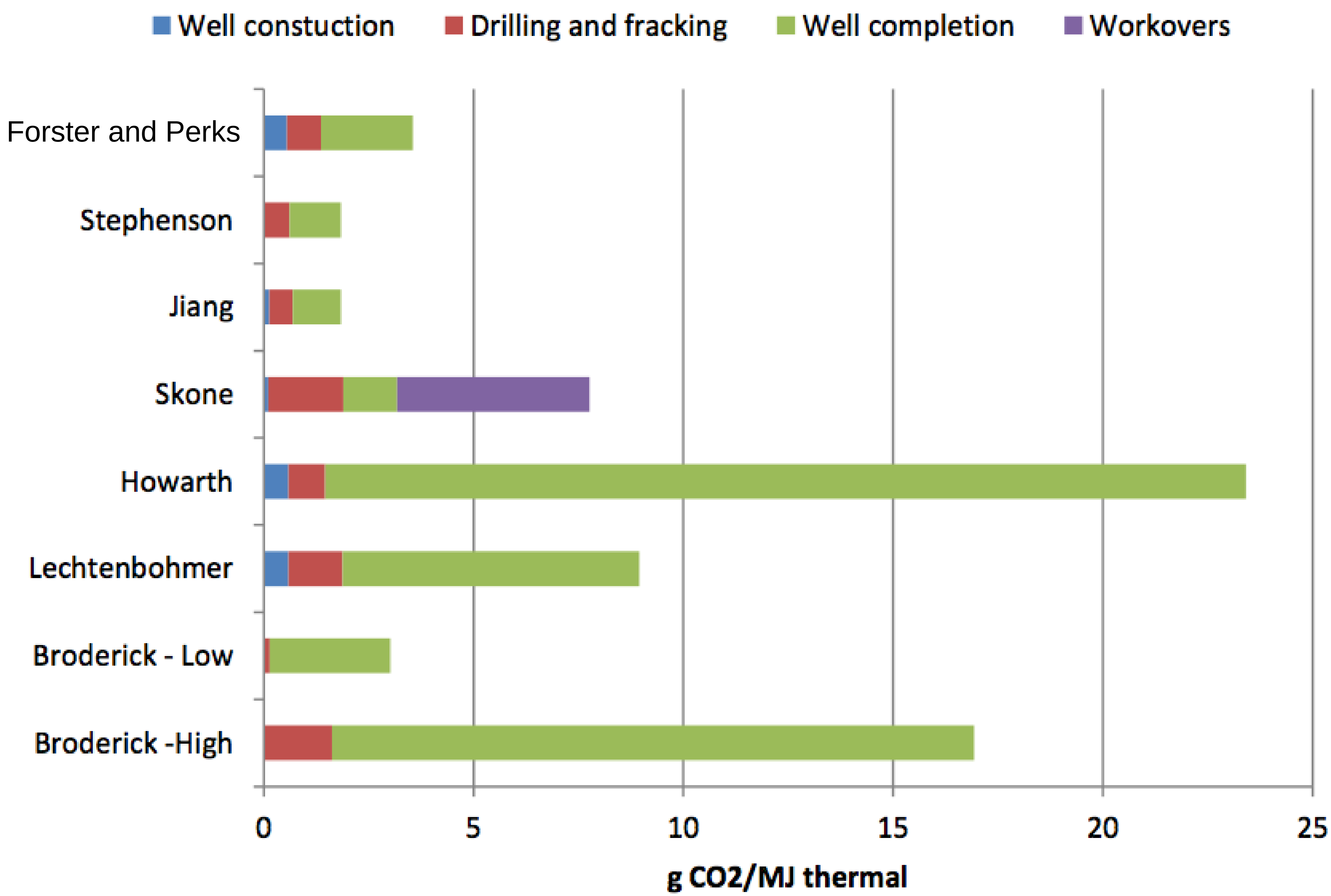
Previous LCAs: Comparison of results



Source: AEA (2012) Climate impact of potential shale gas production in the EU

clare.bond@abdn.ac.uk

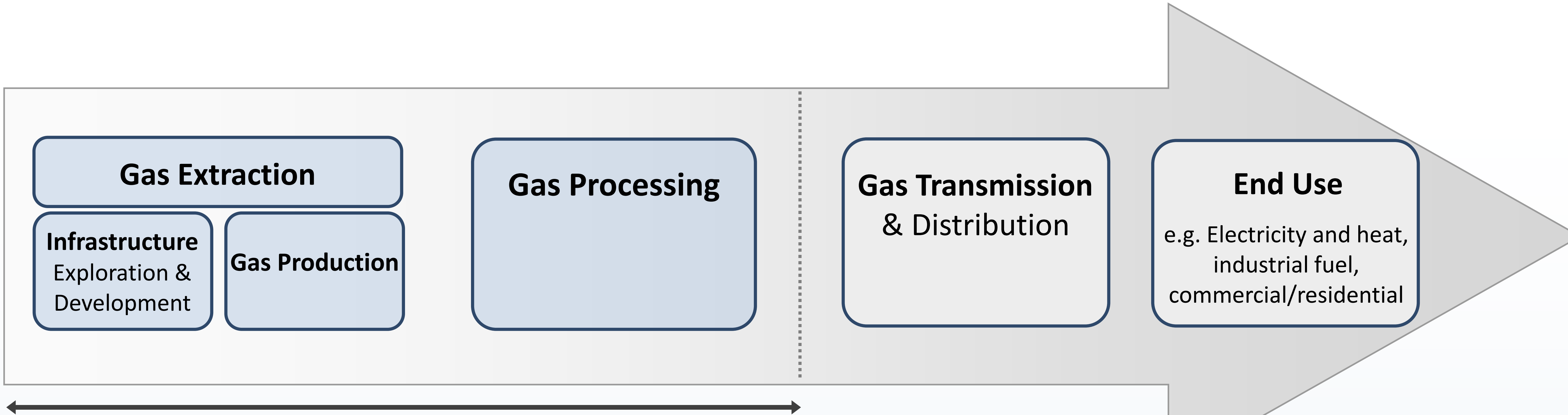
Previous LCAs: Pre-production total



Source: AEA (2012) Climate impact of potential shale gas production in the EU

clare.bond@abdn.ac.uk

Life Cycle Assessment of Shale Gas in Scotland



Scope: gas extraction and processing ('cradle to gate') from shale rocks in Scotland

Scottish Context:

Important difference between potential shale gas practices in Scotland (UK/EU) and practices in the US due to differences in:

- **Regulations**
- **Shale geology**
- **Socio-political context**
- **Infrastructure**
- **Current land-use**

clare.bond@abdn.ac.uk

	Stage	Example activities and potential GHG emission sources
1	**Non-intrusive exploration**	• *Securing of necessary development and operation permits.* • *Site identification, selection, characterisation* • *Exploration surveys (seismic etc)*
2	**Intrusive exploration**	• *Establishing baseline conditions (geochemical, microseismic)* • *Land preparation (land use change)* • *Access road construction* • *Equipment transportation (including water)* • *Exploration well pad construction* • *Exploration drilling: vertical well design and construction.*
3	**Appraisal**	• *Appraisal drilling: horizontal well design and construction.* • *Logging, and well testing* • *Hydraulic fracturing (including flaring) for shale gas.* • *Well completion* • *Dewatering (for CBM)* • *Flow testing, and gas (& oil) production (and processing)* • *Disposal of construction and drilling wastes, and water treatment.*
4	**Production development**	• *Monitoring baseline conditions (e.g. geochemical, microseismic)* • *Land preparation (land use change)* • *Construction of road and pipeline connections* • *Equipment transportation* • *Development well pad and facility construction and installation.* • *Well design construction and completion* • *Disposal of construction and drilling wastes* • *Water treatment (or recycling)*
5	**Production operation and maintenance**	• *Gas/oil production and processing* • *Well work-overs and integrity testing* • *Environmental monitoring*
6	**Well plugging and abandonment**	• *Well plugging and testing* • *Site equipment removal* • *Pre-relinquishment survey and inspection* • *Site restoration and reclamation.* • *Environmental monitoring*

Direct emissions

Direct release of produced gas to atmosphere (from controlled venting or venting of fugitive emissions, i.e. leaks)

Combustion of produced gas as part of controlled flaring or to power onsite machinery

Combustion of other fuels to power onsite machinery or to transport equipment and materials to and from the site.

Indirect emissions

Land clearance to build well pads/roads

Electricity consumption to power the site

Emissions embedded in the sourcing of **purchased materials** and outsourced activities (such as waste treatment and disposal).

clare.bond@abdn.ac.uk

Shale gas extraction: Scotland’s regulatory context

Above: USA

Above: UK; Source: Cuadrilla

EU/UK/Scotland regulation requires:

- **No** open pits for flowback fluids. **Best Available Technology (BAT) to be adopted** e.g. reduced emission completion.
- Venting **only** in emergencies. Proven borehole integrity (construction and monitoring).
- Full disclosure of drilling and fracking chemicals etc.
- Minimal environmental impact from development.
- Permits - activities based.

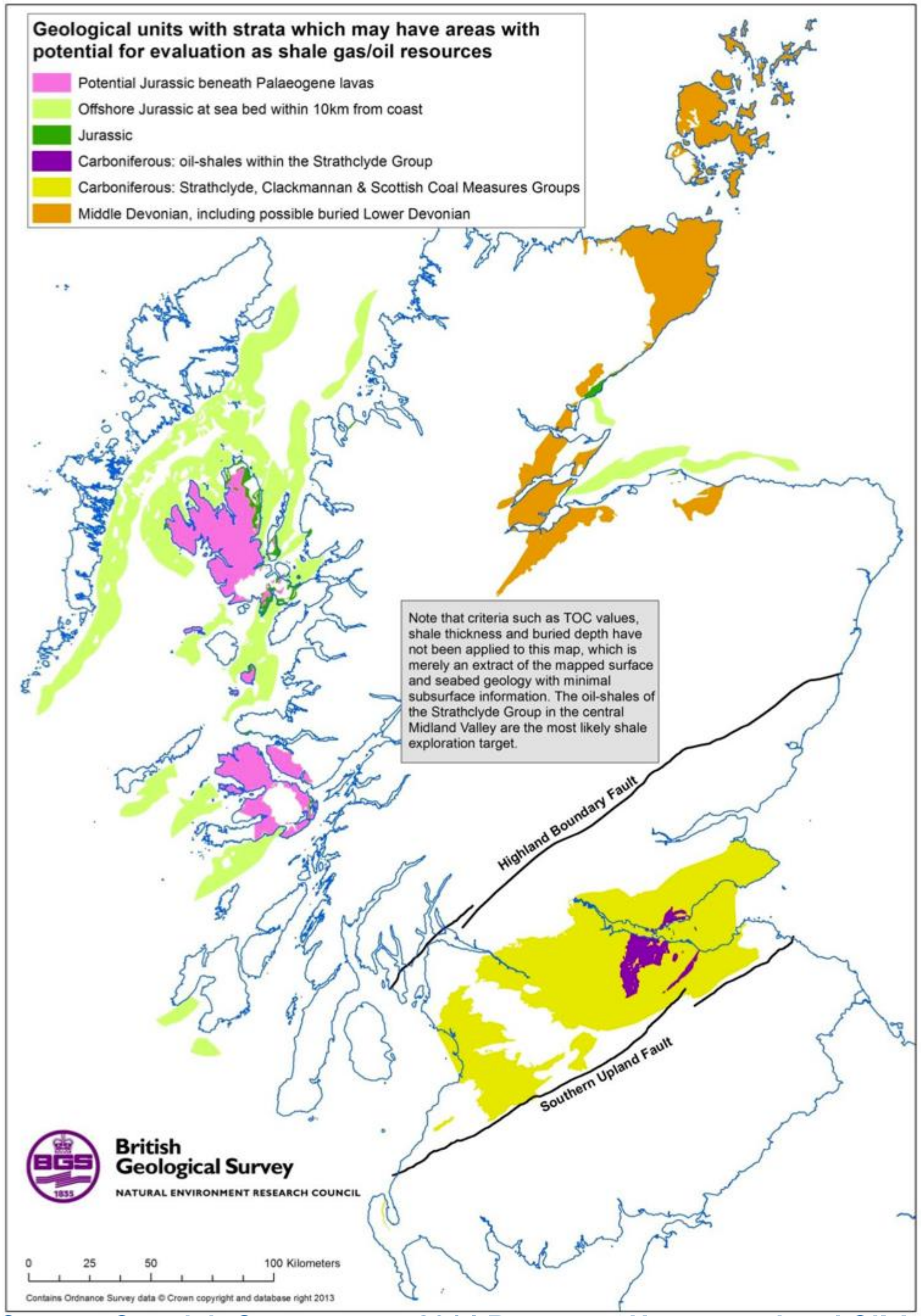
Methane venting vs flaring

Global Warming Potential (GWP) of CH_4 = **36**
New IPCC standard for 100 yr timespan. Revised in 2013 for AR5 (previously 25)

Vent >> **Flare** > **Capture**

clare.bond@abdn.ac.uk

The Scottish Shale Resource

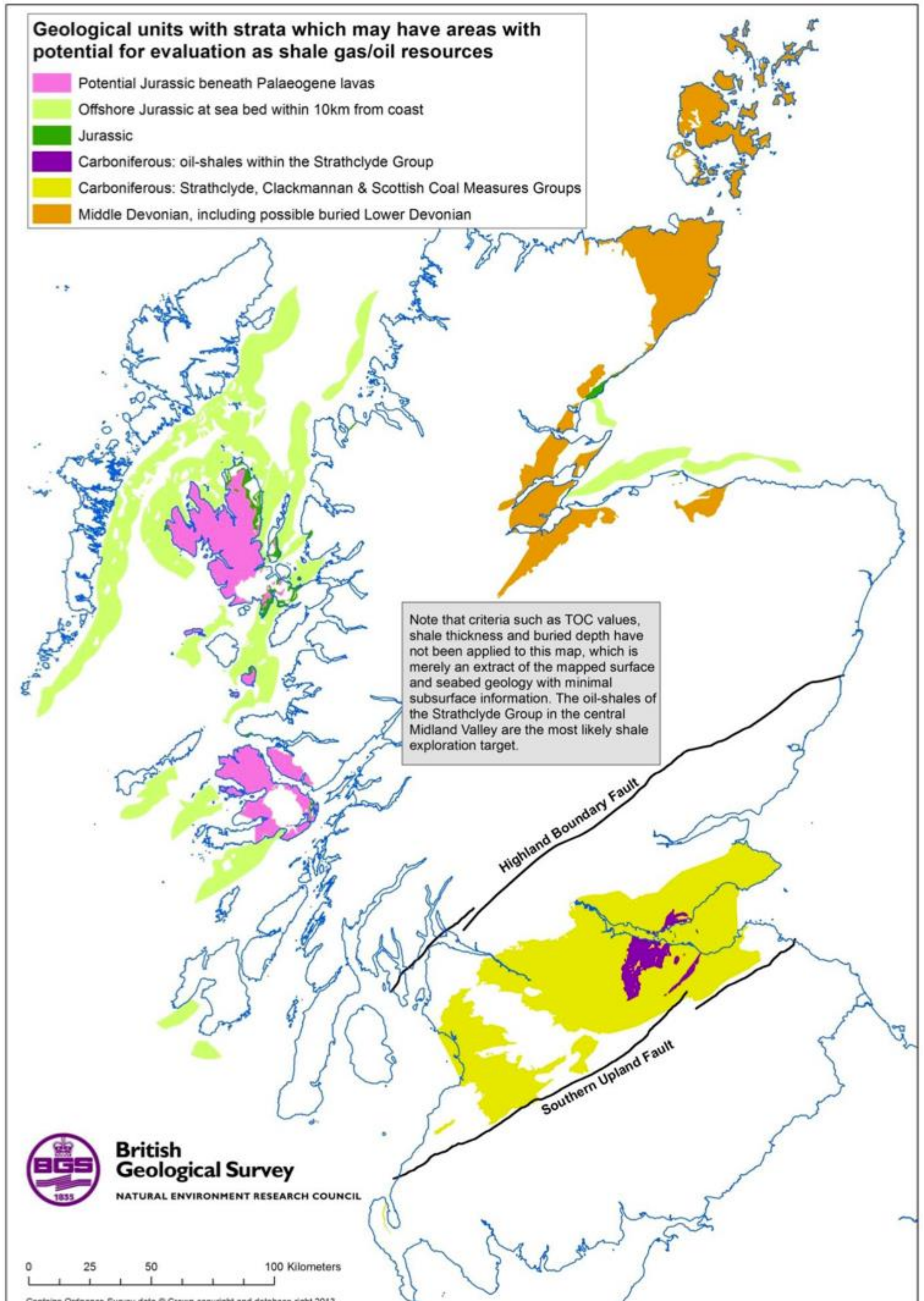


Source: Scottish Parliament Briefing, 2013, Unconventional Gas in Scotland

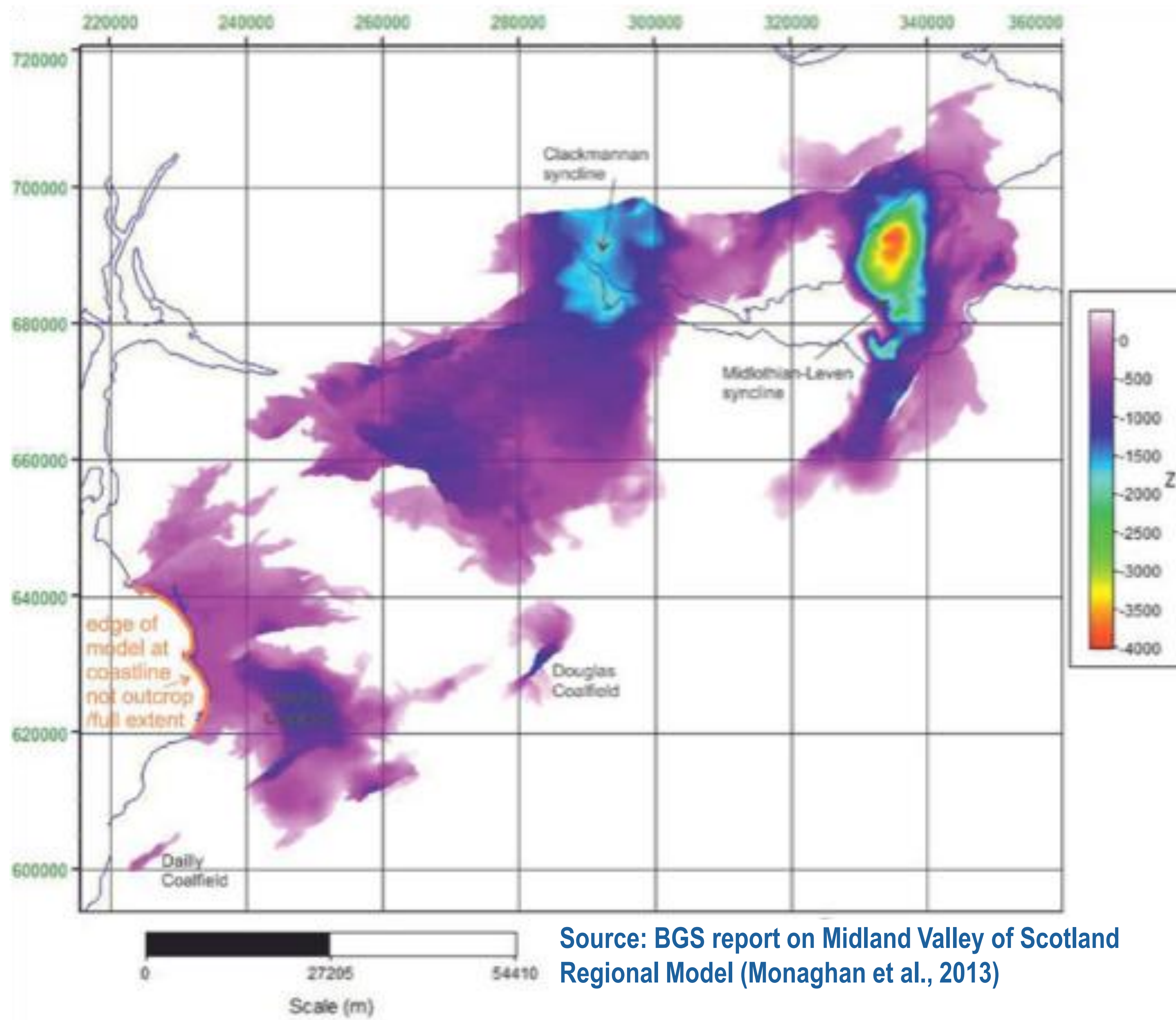
Source: Scottish Government, 2014 Report on Unconventional Oil And Gas (Independent Expert Scientific Panel)

clare.bond@abdn.ac.uk

LCA Shale Gas in Scotland: Shale rocks



Source: Scottish Government, 2014 Report on Unconventional Oil And Gas (Independent Expert Scientific Panel)

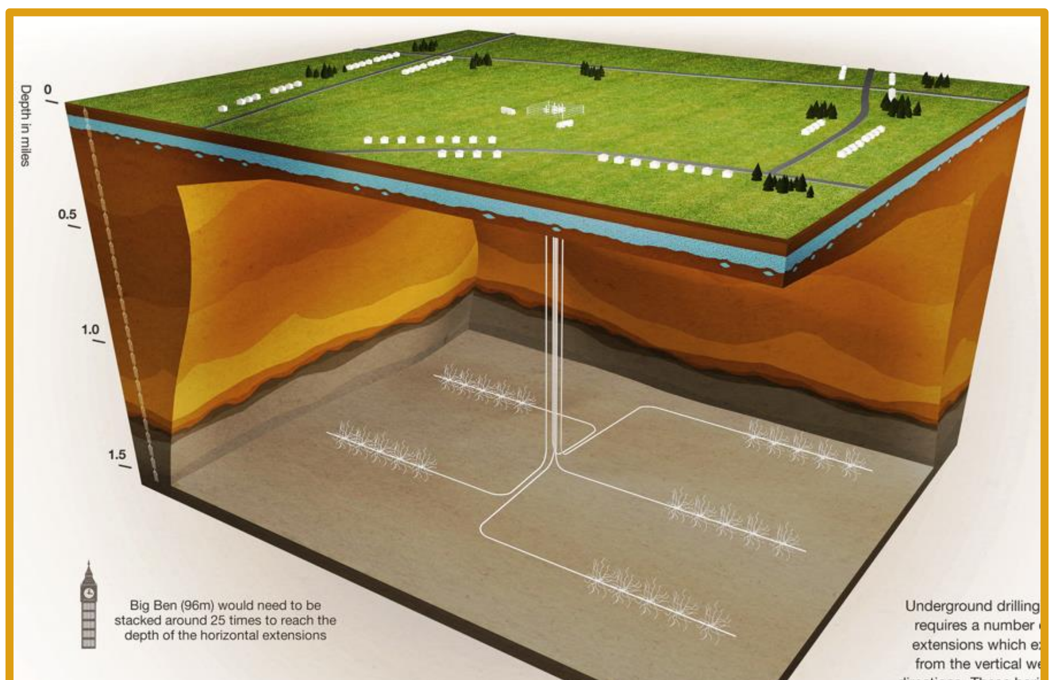


Source: BGS report on Midland Valley of Scotland Regional Model (Monaghan et al., 2013)

clare.bond@abdn.ac.uk

LCA Shale Gas in Scotland: Socio-political context

Source: Ecowatch



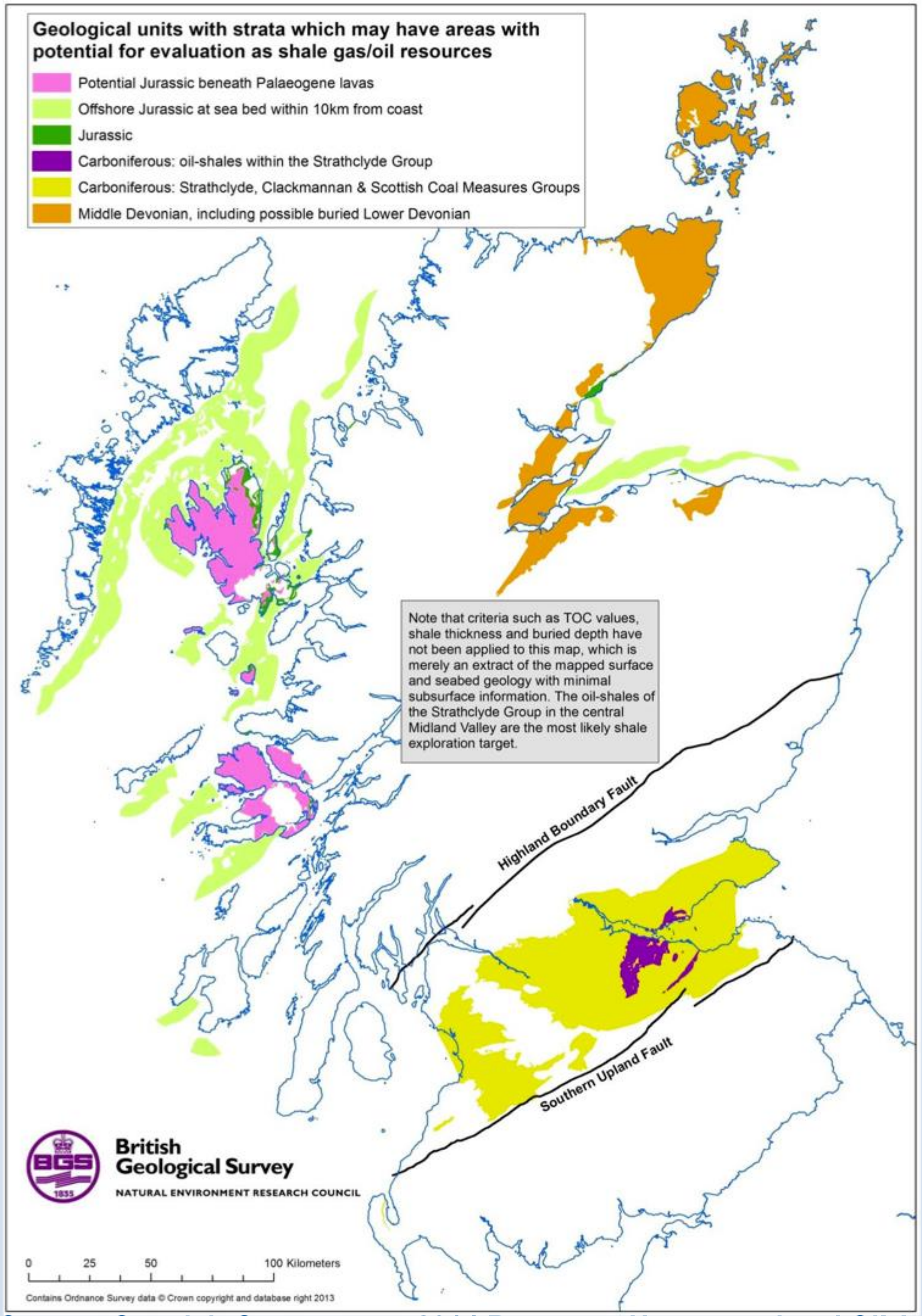
Source: DECC

Compared to the US/Canada/AUS, Scotland has:

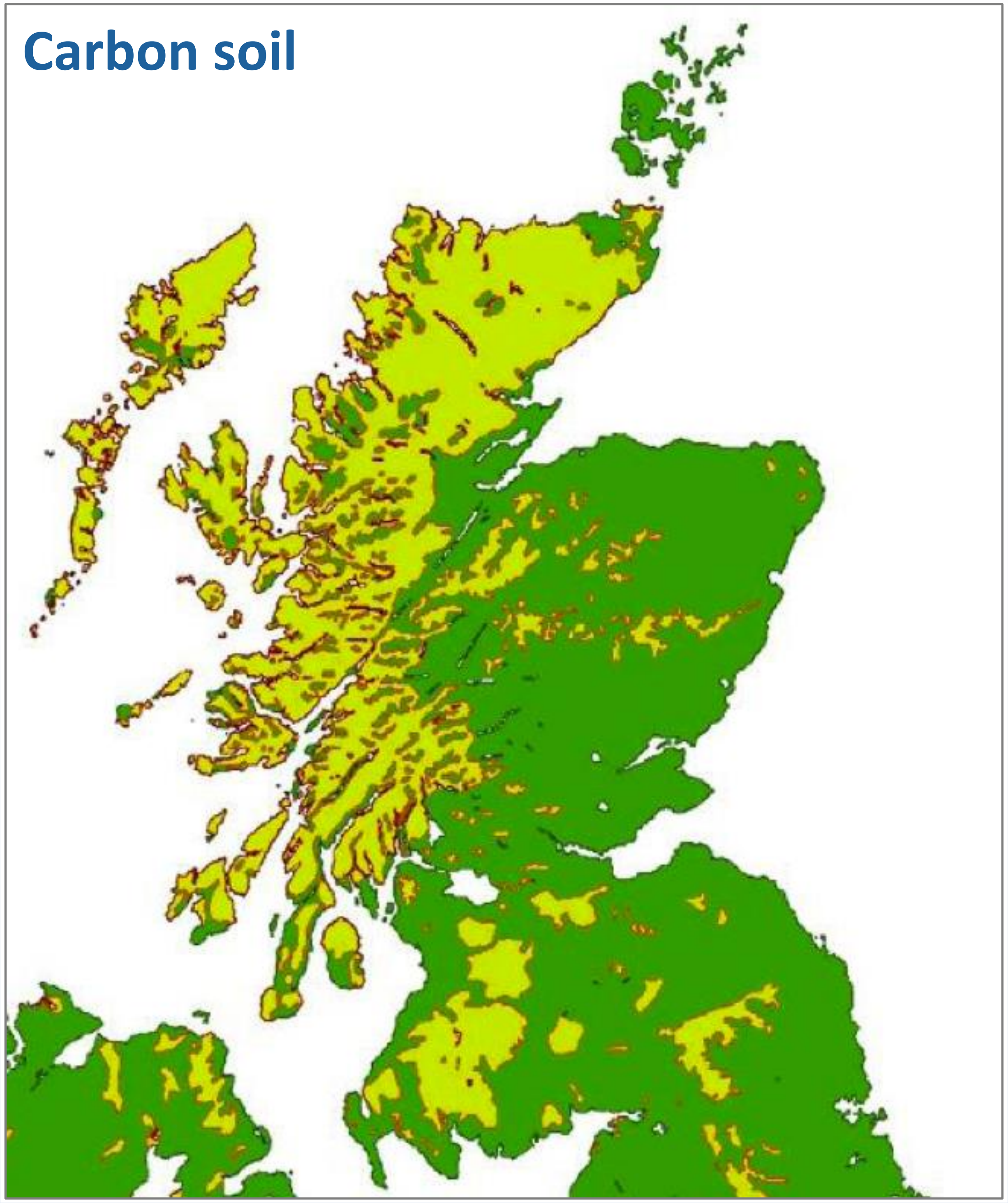
- **Dense infrastructure** (in Midland Valley), reduces the transport distances of materials.
- Gas and water pipeline connections.
- Less land clearance for e.g. new roads
- **Different social factors** e.g. population density and social license to operate.
- Pad density likely to be lower.

clare.bond@abdn.ac.uk

LCA Shale Gas in Scotland: Land use



Source: Scottish Government, 2014 Report on Unconventional Oil And Gas



Source: World Soil Data (JRC, 2013)

climate change Scotland's centre of expertise connecting climate change research and policy

clare.bond@abdn.ac.uk

LCA Shale Gas in Scotland: Method/Assumptions

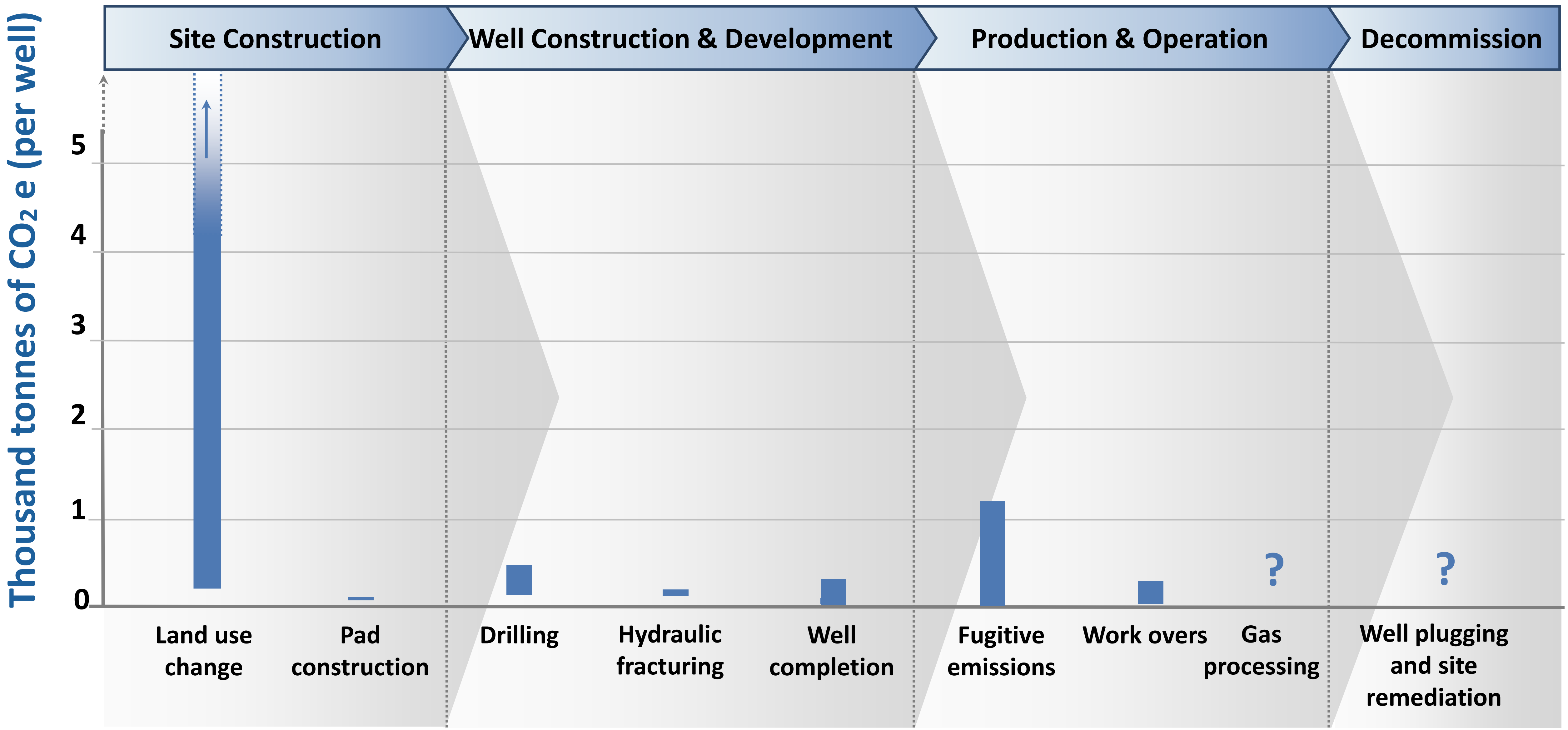
=> Used published data from LCAs

=> Where possible adapted to Scottish context

- Average shale depth of 2.4 km.
- 100% capture & flare, or 100% capture for potential emissions from well clean-up.
- Adopt Mackay & Stone (2013) **EUR** scenarios per well: 2, 3, 5 bcf per well.
- Adopt Mackay & Stone (2013) assumption of 10 well pad, one horizon, 15,000 m^3 water to frack.
- Water treated off site, use **Defra** values for water treatment.

clare.bond@abdn.ac.uk

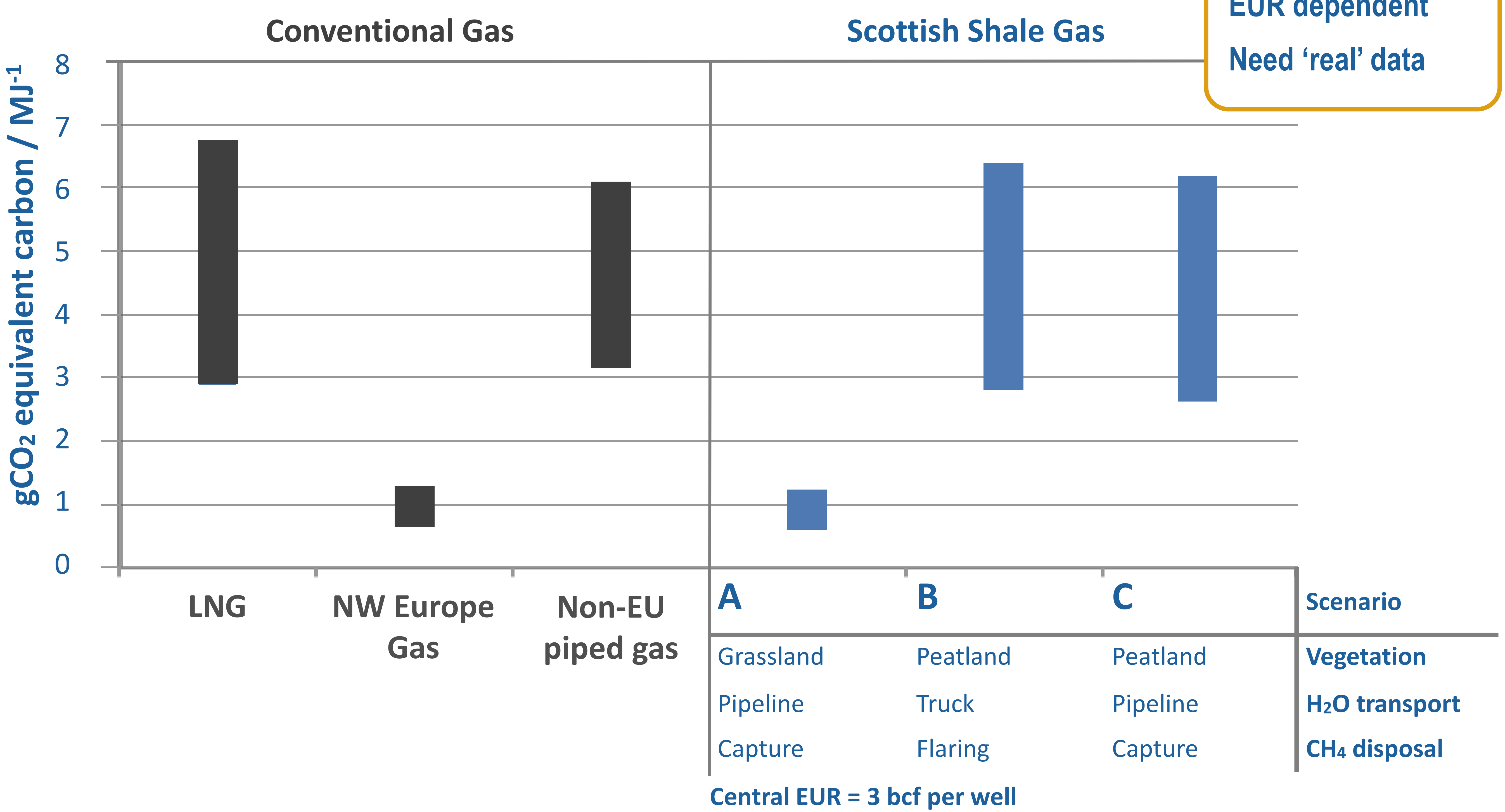
LCA Shale Gas in Scotland: Results



Land use change max = 11.4

clare.bond@abdn.ac.uk

LCA Shale Gas in Scotland: Results



EUR dependent
Need 'real' data

clare.bond@abdn.ac.uk

Implications and recommendations

Overall

- The life-cycle GHG emissions **per unit of energy** from **shale gas** extraction in **Scotland** are likely to be **equivalent** to those of **conventional** gas extraction in Europe **if best practice is followed and building on peat is avoided.**

- **This is dependent** on the total quantity of gas recovered from extraction operations.

clare.bond@abdn.ac.uk

Implications and recommendations

Land use change

- **Minimise** the **area** of developed land (incl. roads and pipelines - utilise existing where appropriate, or e.g. polyplastic unburied water pipeline).
- **Maximise** the number of boreholes at each well pad
- **Avoid** exploration and development on **peatland**

Fugitive emissions

- We need an **inventory** - since emissions are very uncertain.
- **Improved performance** of valves, pumps, compressors (**improved BATs**)
- Implement Leak Detection and Repair (**LDAR**) programmes for rapid remediation of leaks

clare.bond@abdn.ac.uk

Implications and recommendations

Methane emissions during well completion

- **Ensure that BATs are applied** - and continue to **improve** BATs to minimise emissions.
- **Utilise** captured methane rather than flare.

Other options

- **Recycle** water and materials (e.g. drill mud, water, and proppant) where possibleMinimise emissions where health and safety and social penalties of doing so are minor
- **Power sites** by produced or captured natural gas rather than diesel.
- **Centralised processing** facility - gas from several well pads - to minimise infrastructure.

But there are large uncertainties

Improved life-cycle emissions estimates can be made with improved resource assessment, improved understanding of fugitive emissions and real data.

clare.bond@abdn.ac.uk

Scottish Government Independent Expert Scientific Panel on Unconventional Oil And Gas

*"**mitigating** a potential or realised **impact** depends on strong and visionary **environmental, and health and safety**, **regulators** to enforce legislation and **identify and respond rapidly to gaps that may emerge**."*

1495 UNIVERSITY OF ABERDEEN

University of Strathclyde Glasgow

British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL

clare.bond@abdn.ac.uk