



Wir schaffen Wissen – heute für morgen

Shale gas: The environmental performance from the life cycle perspective

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Life Cycle Assessment – LCA

Goal: Complete accounting for environmental burdens associated with the production/consumption of goods & services

→ allows fair comparison of options fulfilling the same need

Energy Systems: Full energy chains (from resource extraction to end use)

e.g.

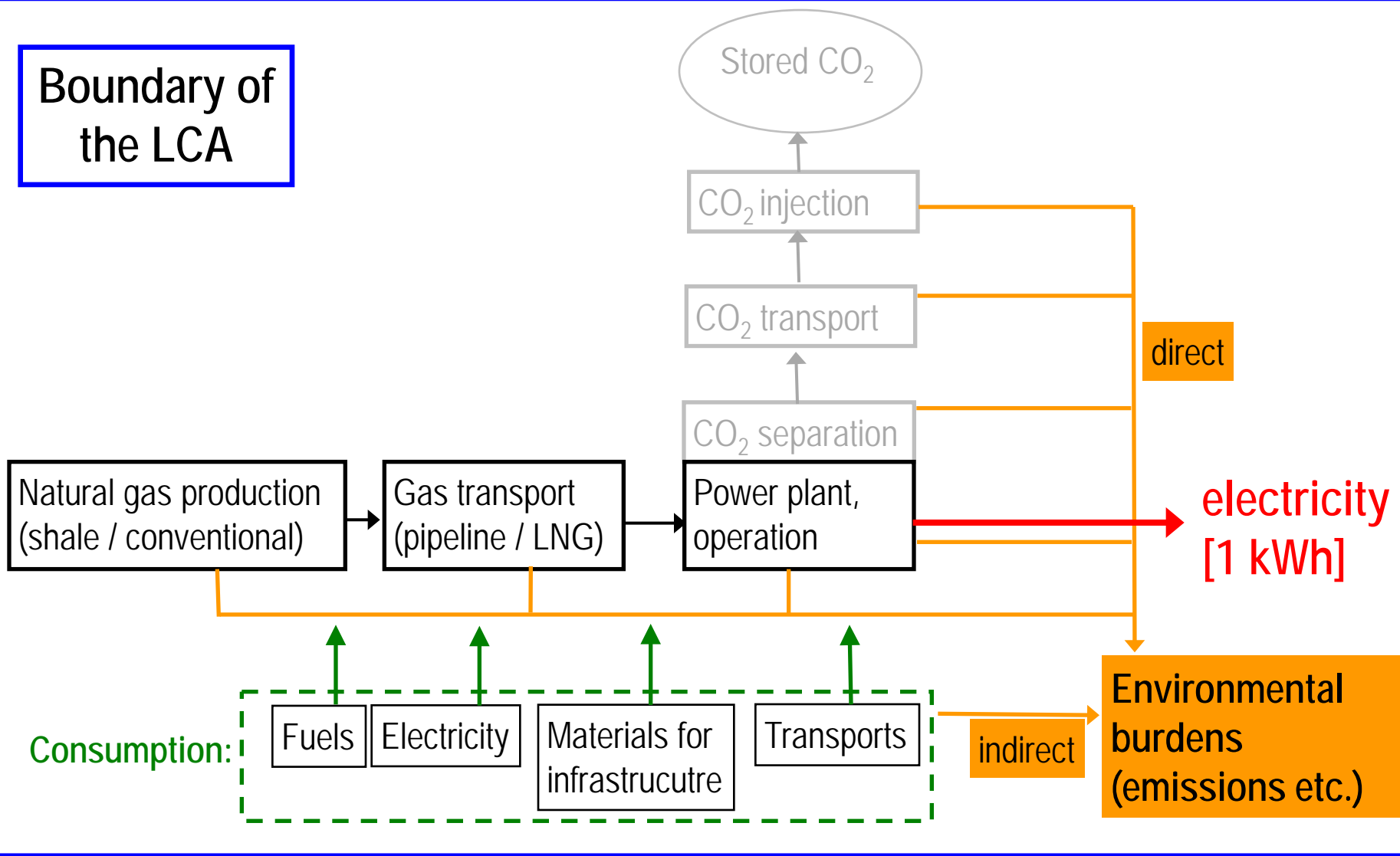
- options for **electricity production:**

fossil ↔ nuclear ↔ renewables

- use of alternative **transport fuels:**

natural gas ↔ diesel ↔ gasoline ↔ agrofuels ↔ H₂ ↔ electricity

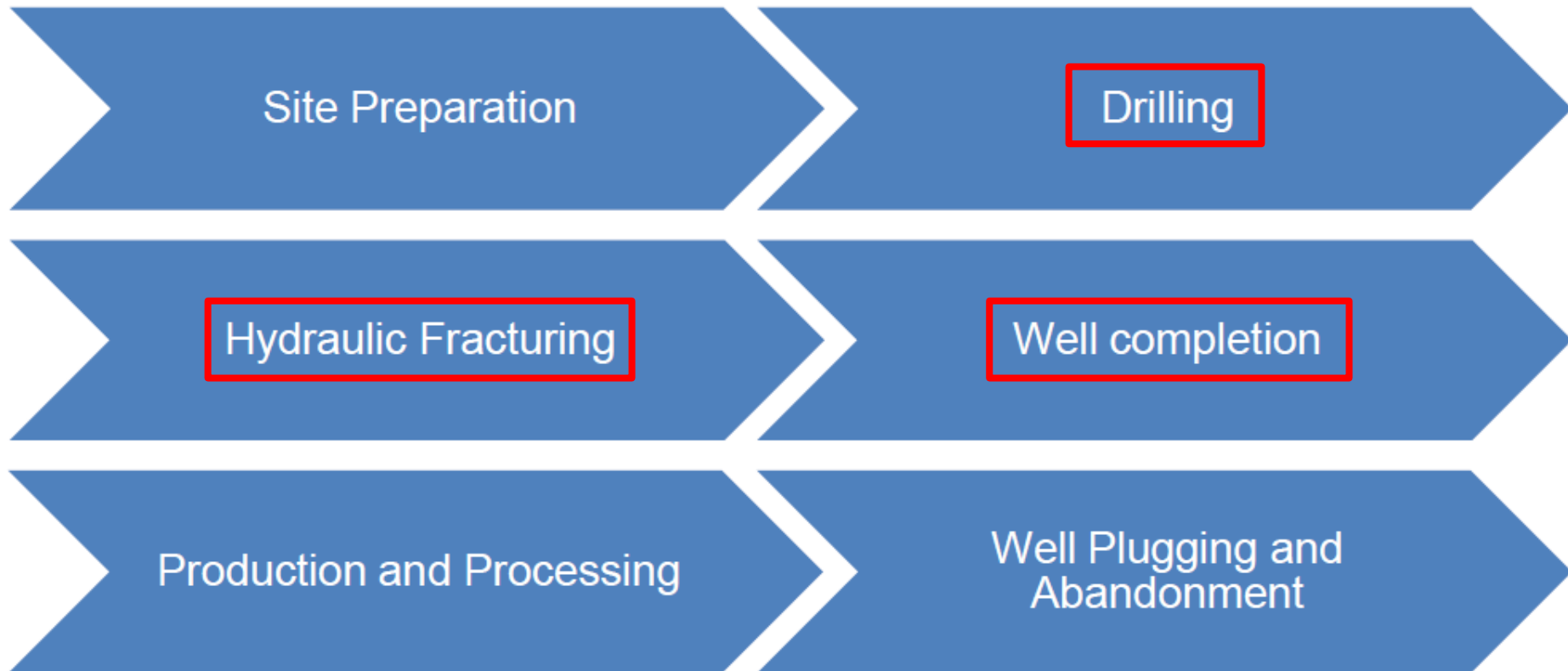
LCA model of the natural gas chain with CCS



LNG: Liquid Natural Gas

CCS: Carbon Capture & Storage

Relevant processes in the shale gas production chain



- Drilling:** more drilling required than for conventional gas
- emissions from drill rig (diesel generators)
 - emissions associated with casing of boreholes
 - potential leaking of drilling fluids / mud

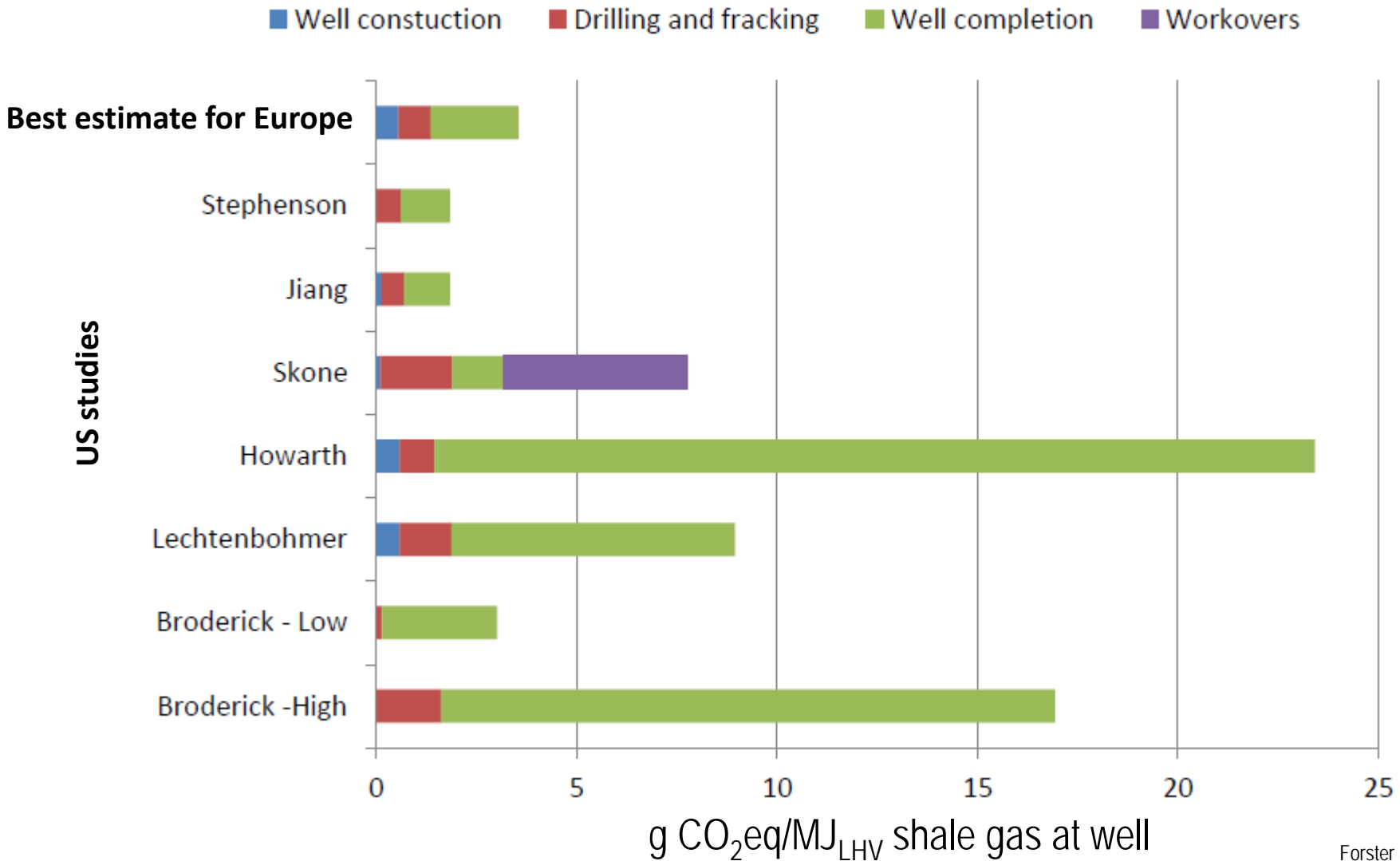


Fracturing & well completion: stimulation of wells

- **Fracturing fluids:** mixture of water, chemical additives & proppants
 - High water demand
 - Potential surface / groundwater contamination
 - CH₄ emissions as part of «flow back fluid»
 - flow back might contain trace elements, radioactive substances, organic compounds
- **Mitigation strategies:**
 - re-use of water
 - “green completion” reducing CH₄ emissions
 - flaring of CH₄
 - appropriate wastewater treatment

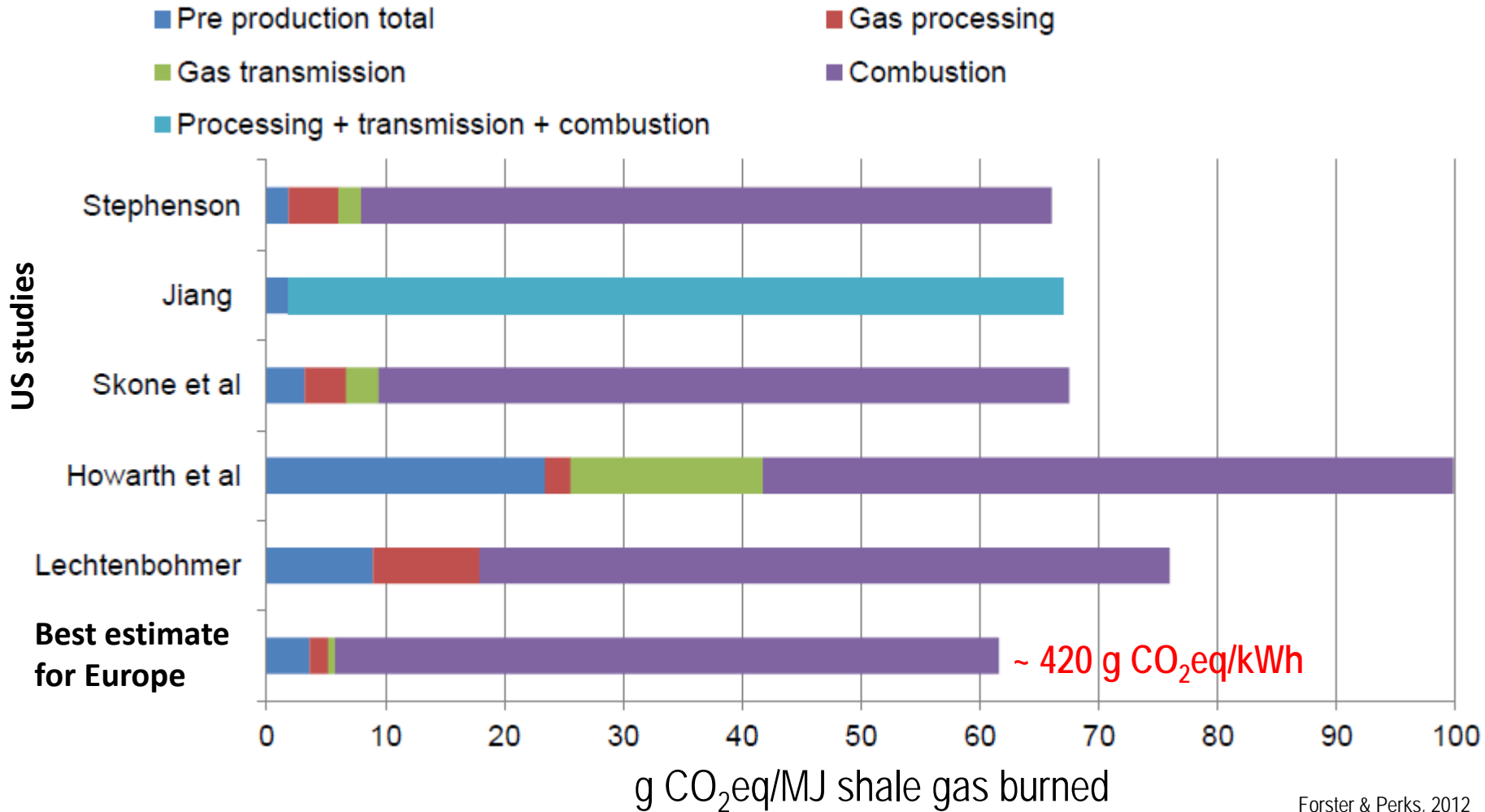
- **Limited number of independent LCA studies** available (~5)
- Mostly **based on** experience from the **US** (few shale beds and well sites)
- **End-use technology: electricity generation** (transport fuel)
- Focus on Greenhouse Gas (GHG) emissions and **water consumption**
- **Large uncertainties, variations and data gaps**
- Extrapolation to European conditions not straight-forward
- Few **critical parameters** identified:
 - **CH₄ „loss rate“** (due to flowback and other leaks)
 - **CH₄ venting/flaring** rate
 - **Well productivity**
 - (potential water contamination)

Pre-production stages of shale gas (gas at well)



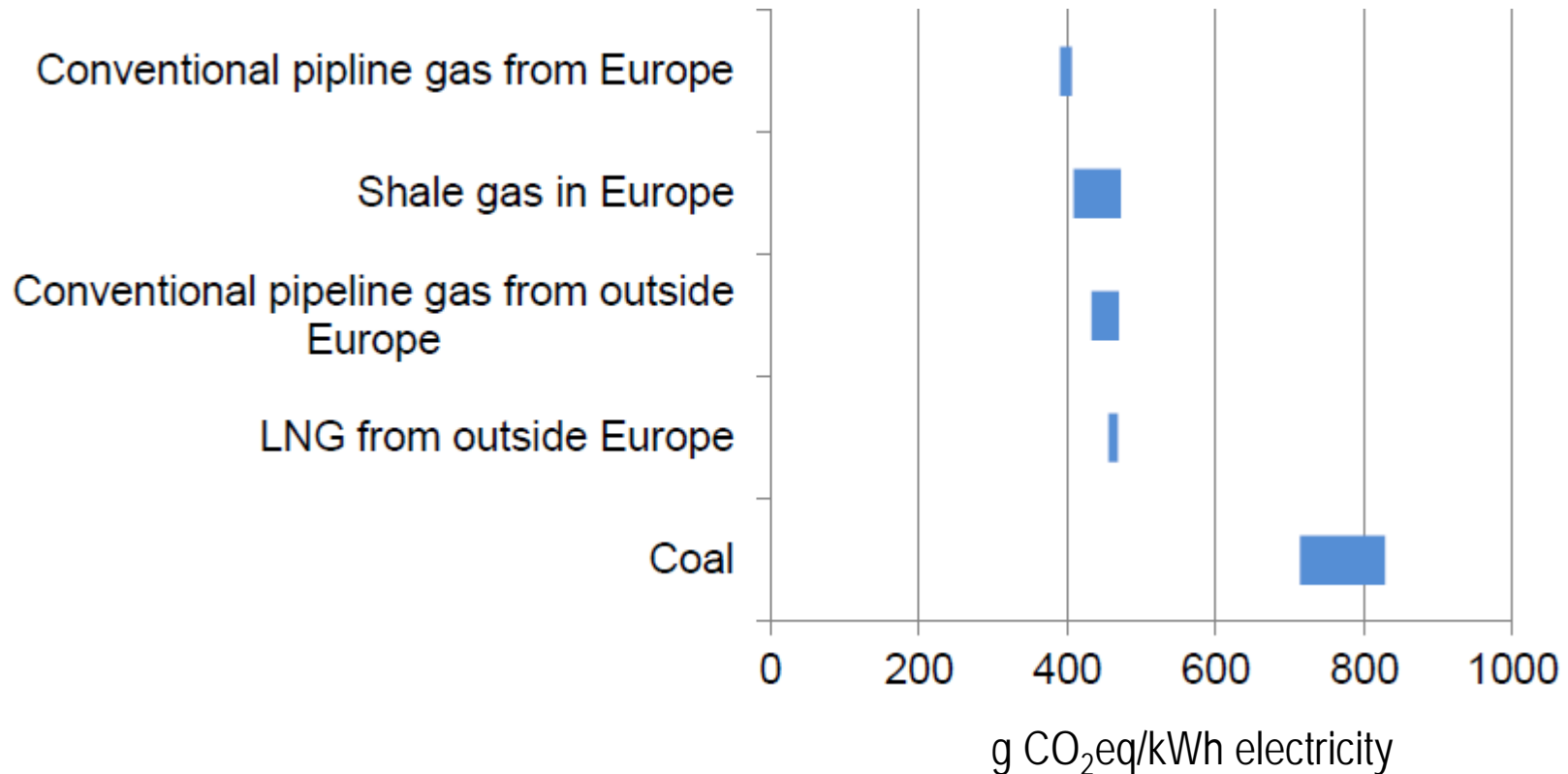
Forster & Perks, 2012

Combustion of shale gas

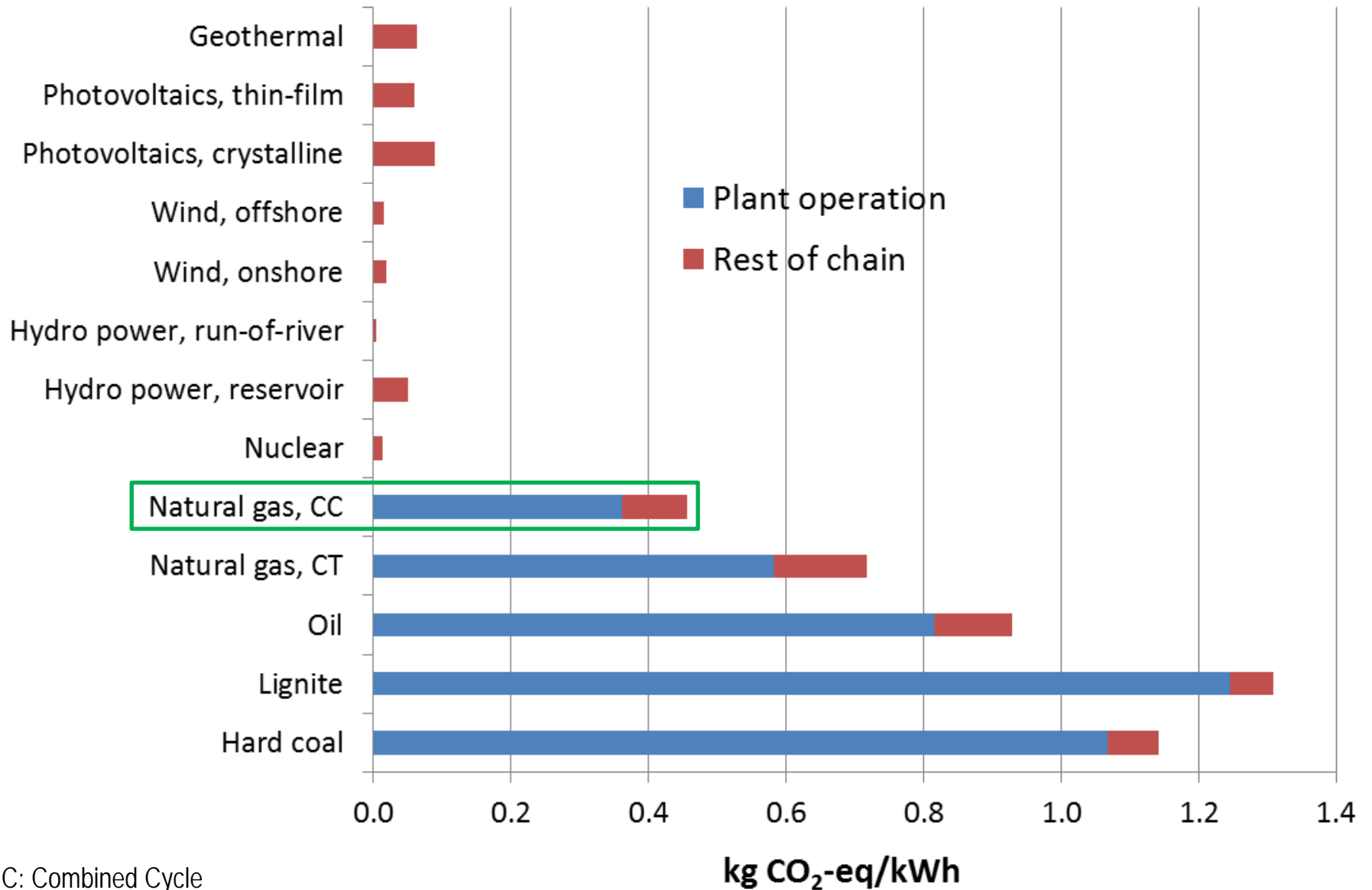


Forster & Perks, 2012

Electricity production: effect of different fossil fuels

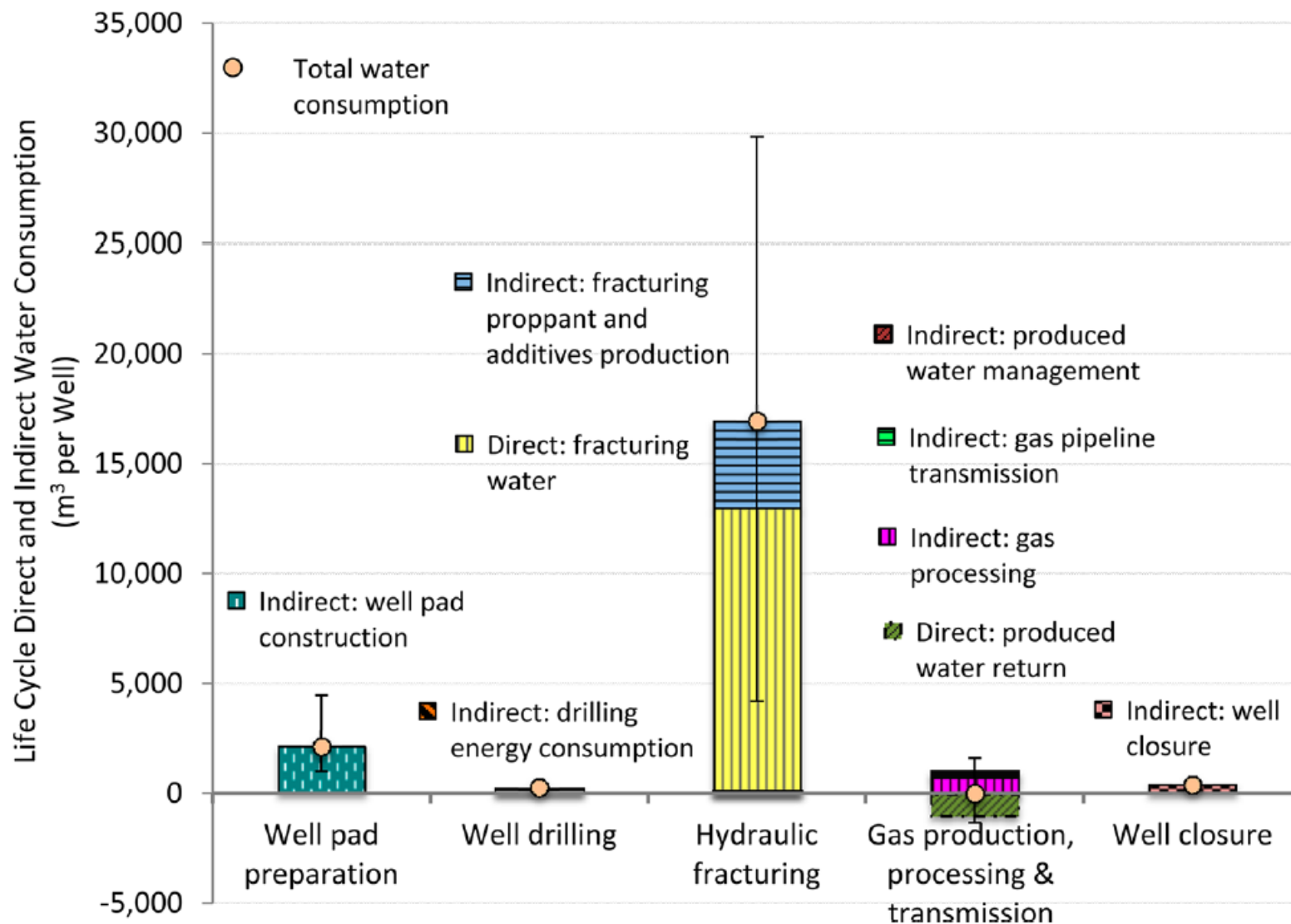


LCA results: GHG_{GWP100a} emissions

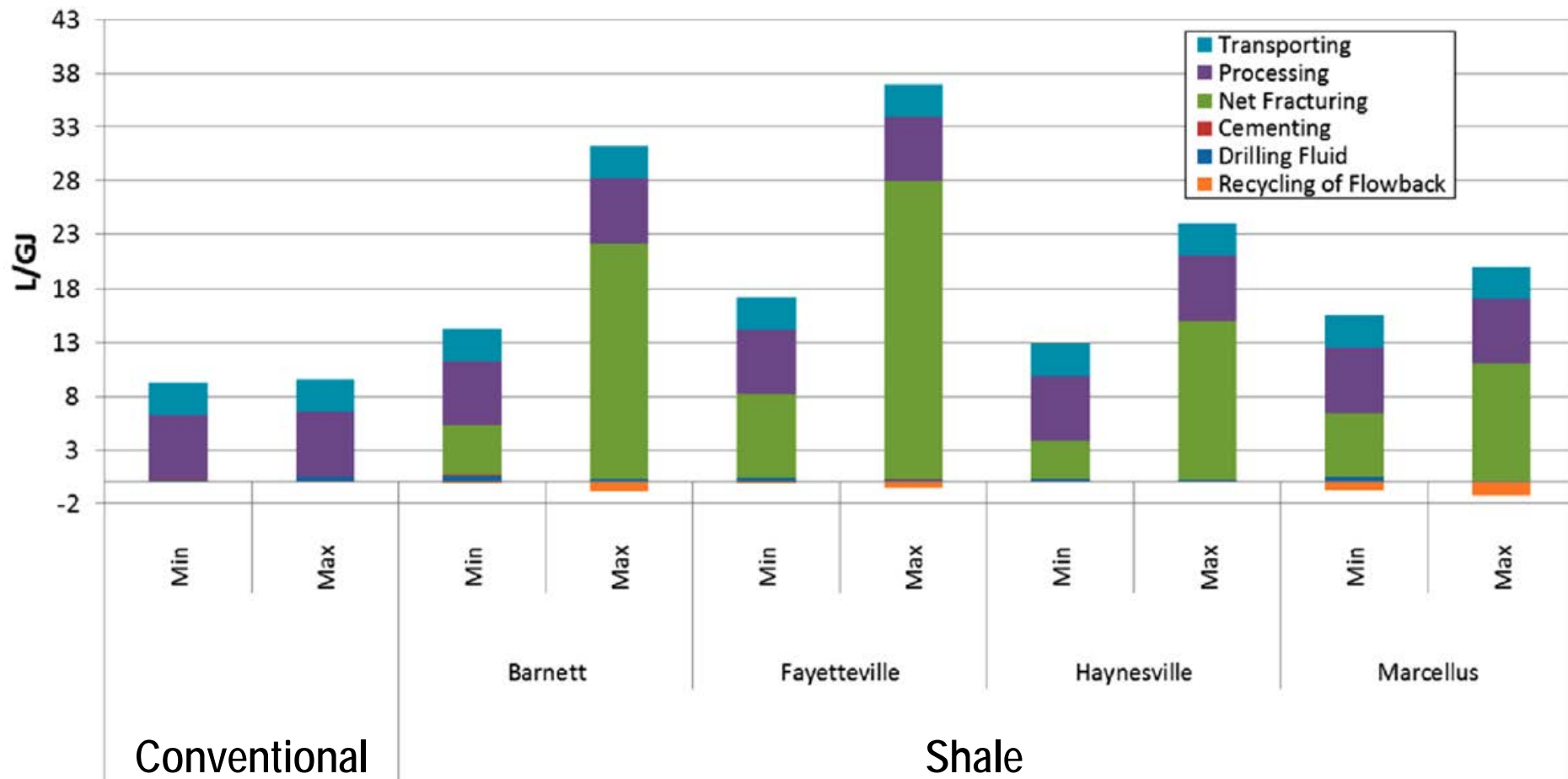


CC: Combined Cycle
CT: Conventional Turbine

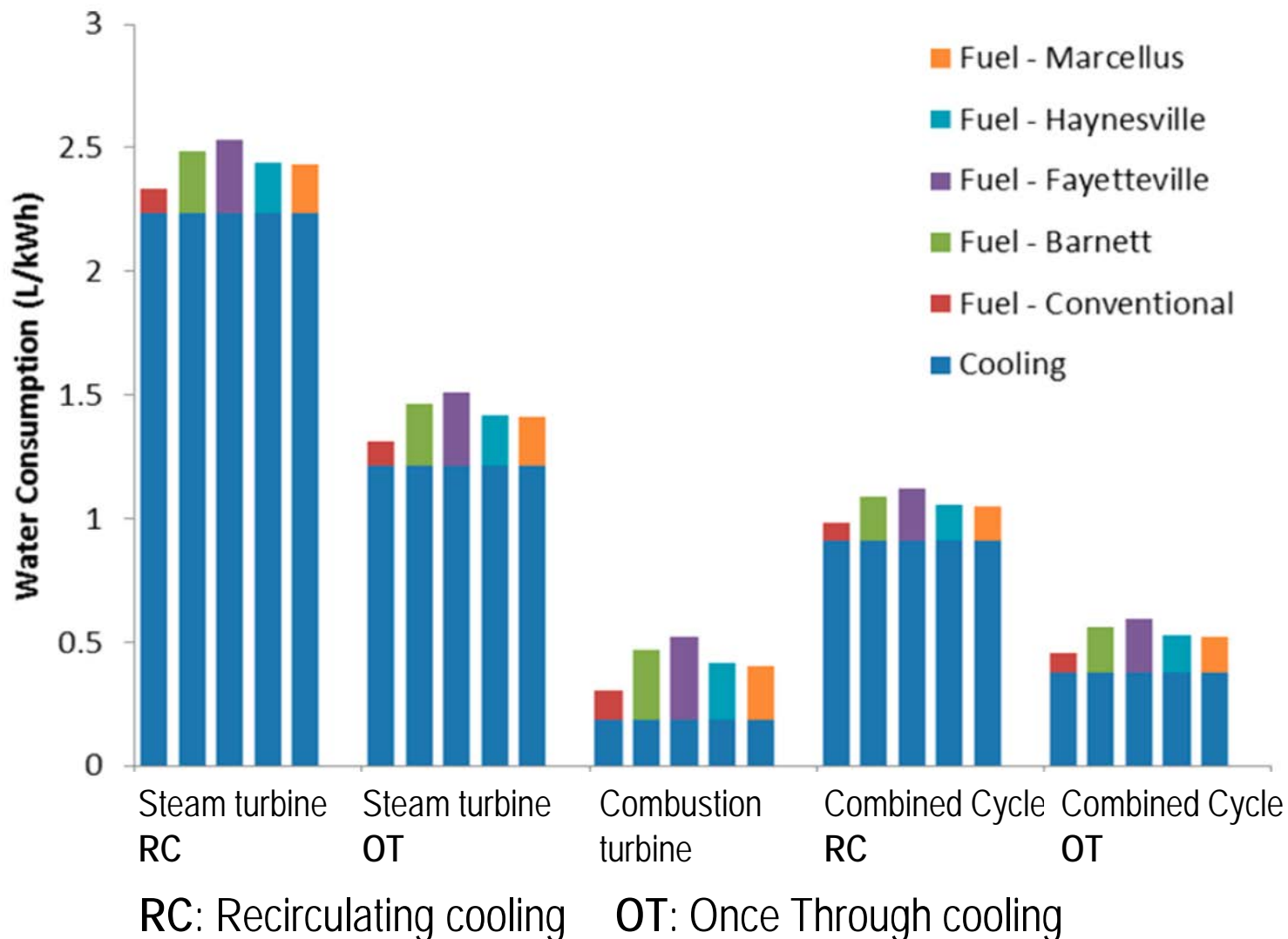
Water consumption: shale gas production stages



Water consumption: shale gas vs. conventional gas production



Water consumption: gas powered electricity generation



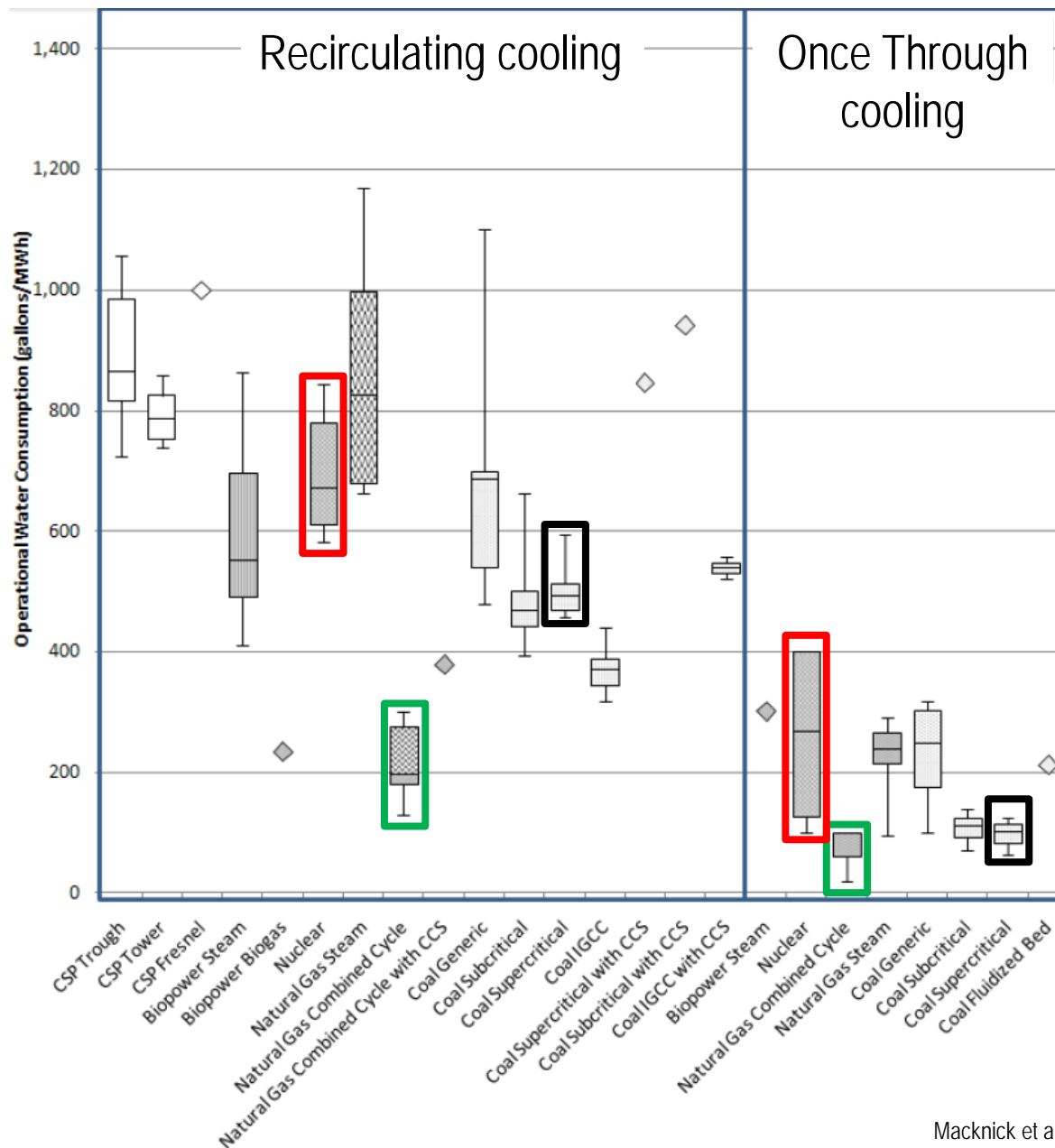
LCA results: water consumption

Water consumption:
electricity generation

Natural gas CC (modern)

Coal (modern)

Nuclear





LCA: summary of the current status

- ✓ good
- ✗ bad
- ambiguous

	Coverage	Data availability	Data quality	Validity for CH / Europe
GHG emissions / climate impacts	✓	✓	○	✓
Water consumption	✓	✓	○	○
Water pollution	○	✗	✗	✗
Other impacts on environment & human health	✗	○	○	○

- **Climate change impact of shale gas electricity generation:**
Similar to conventional gas, ~ ½ of coal
- **Water consumption:**
Will be an issue in arid areas; not so much from the life cycle perspective
- **Further impacts on human health & ecosystems:**
Not yet quantified due to lacking data
- **Important for Europe:**
Smart regulation framework

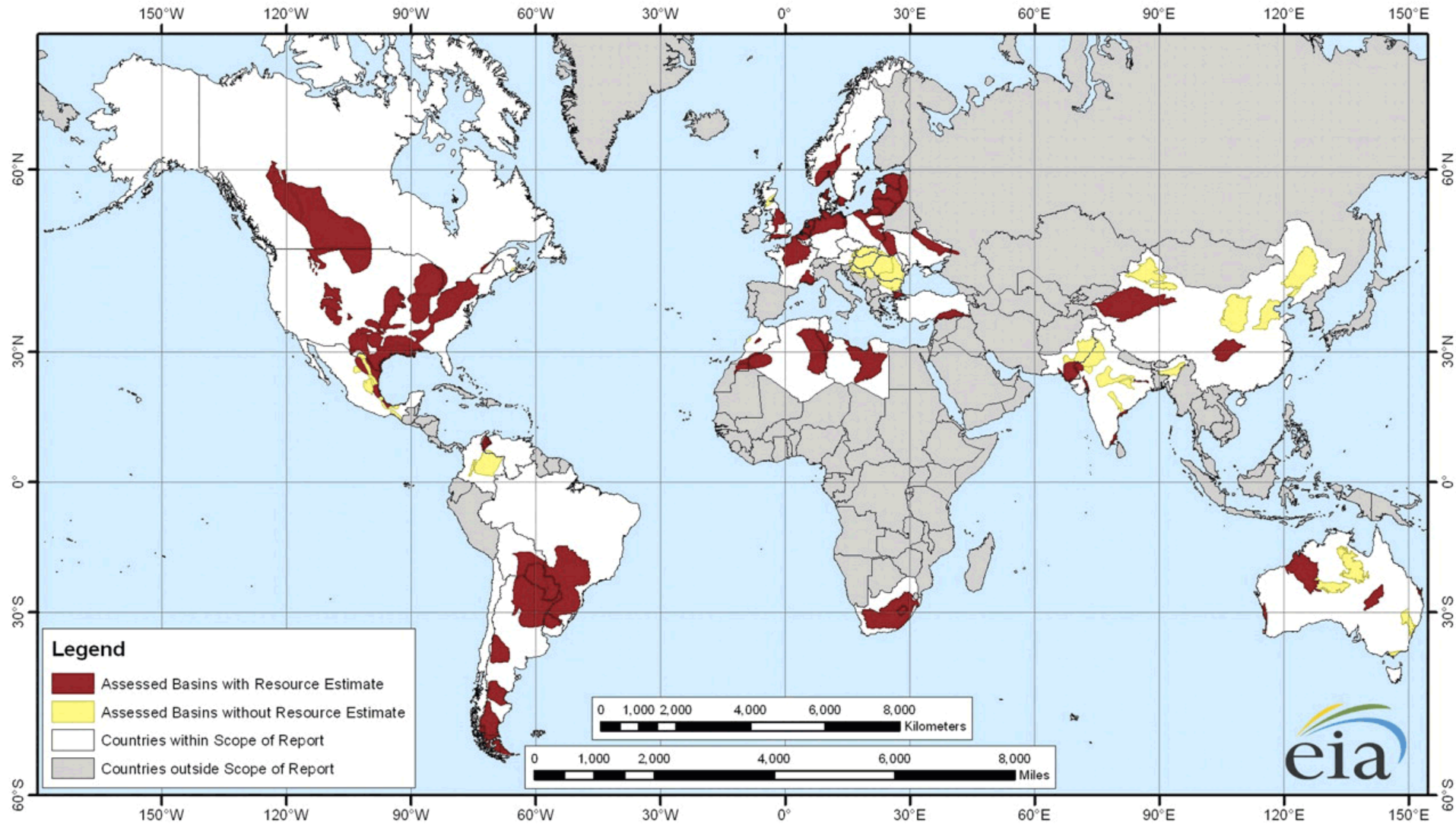
→ further research required for a complete picture of the environmental performance of shale gas, especially in Europe

Contact and more information:

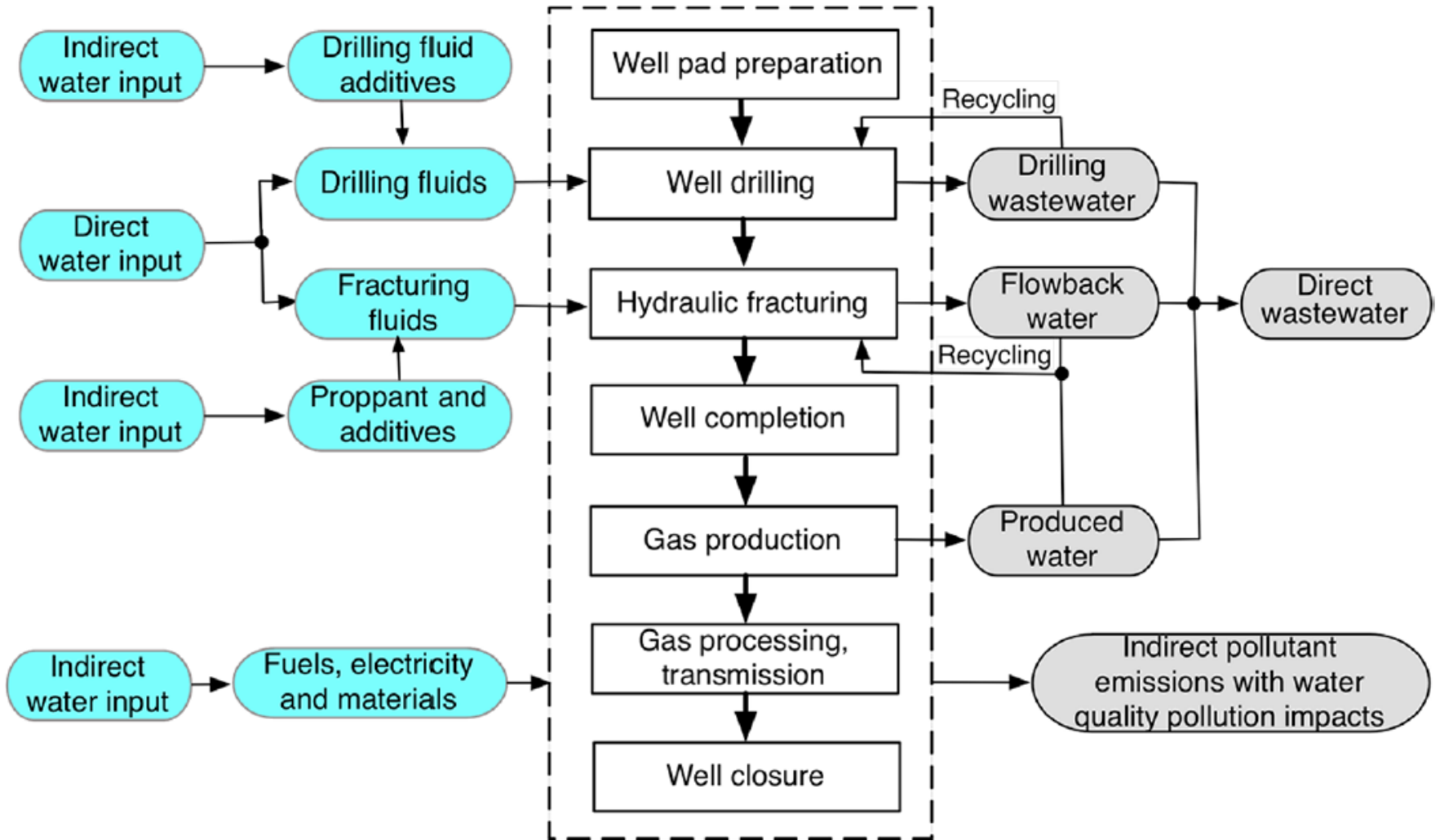
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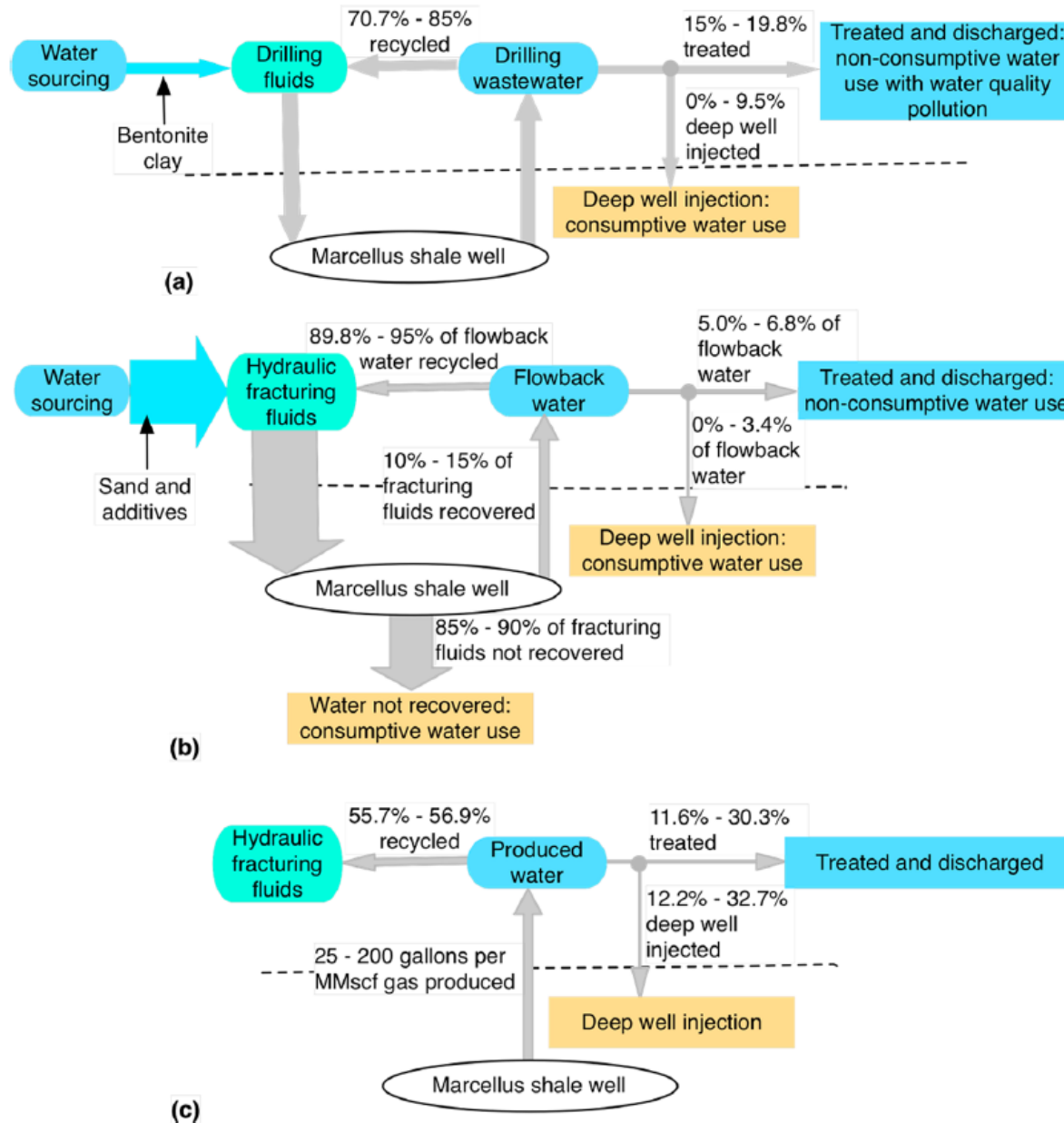
Illustration of global natural gas deposits



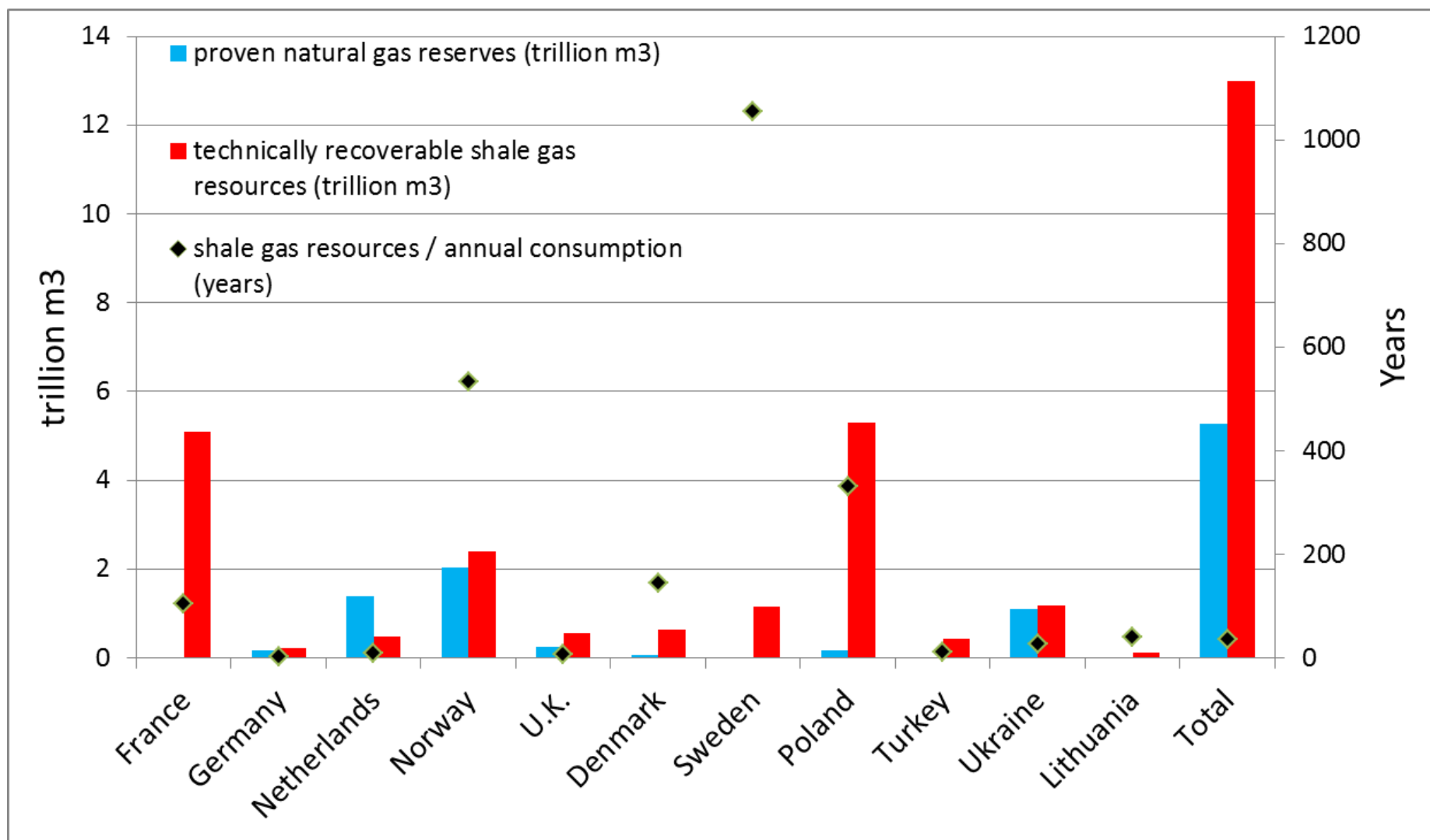
Water flows in shale gas production



Water flows in shale gas production

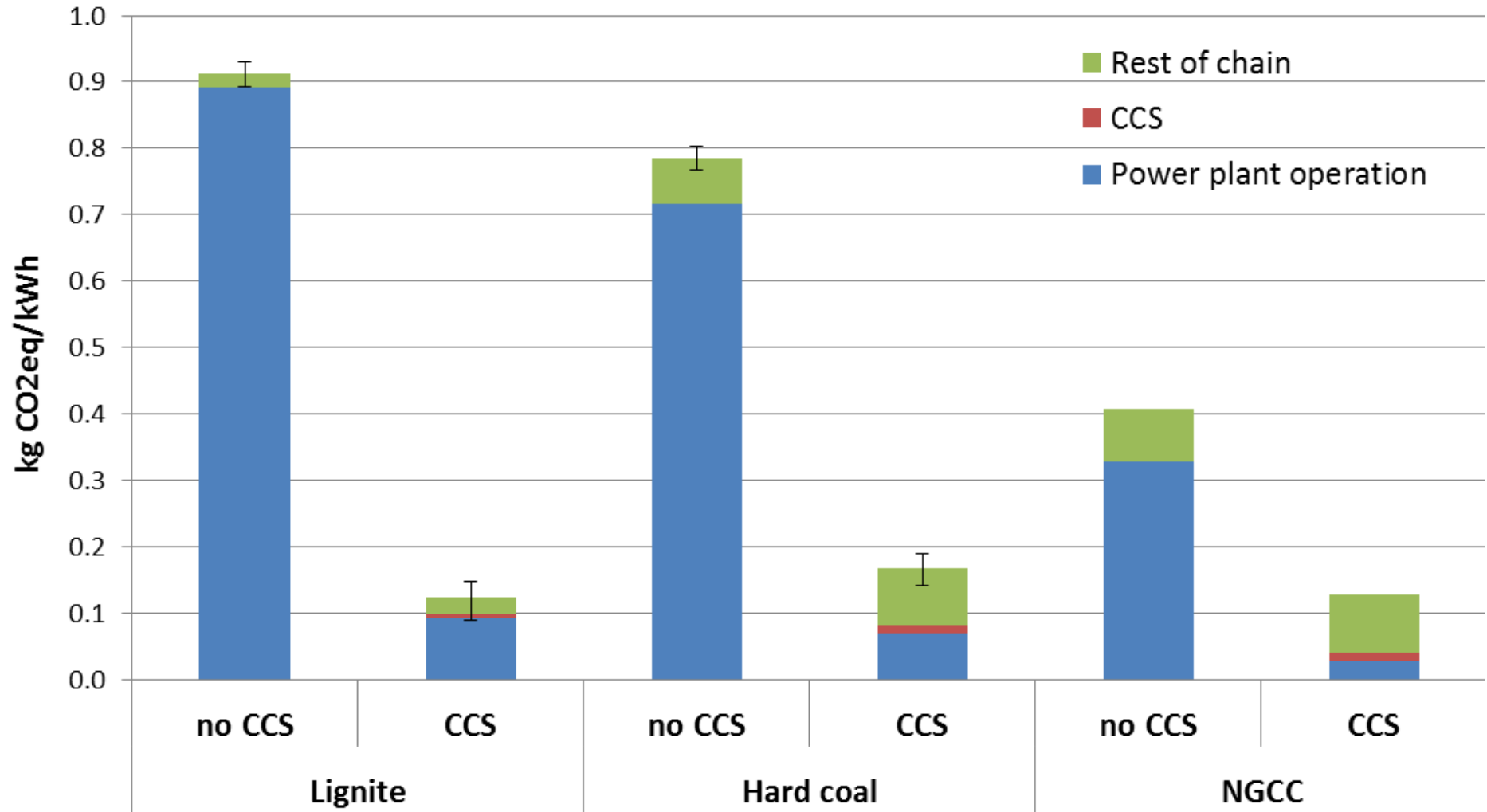


Natural gas in the EU



Adapted from: Forster & Perks, 2012

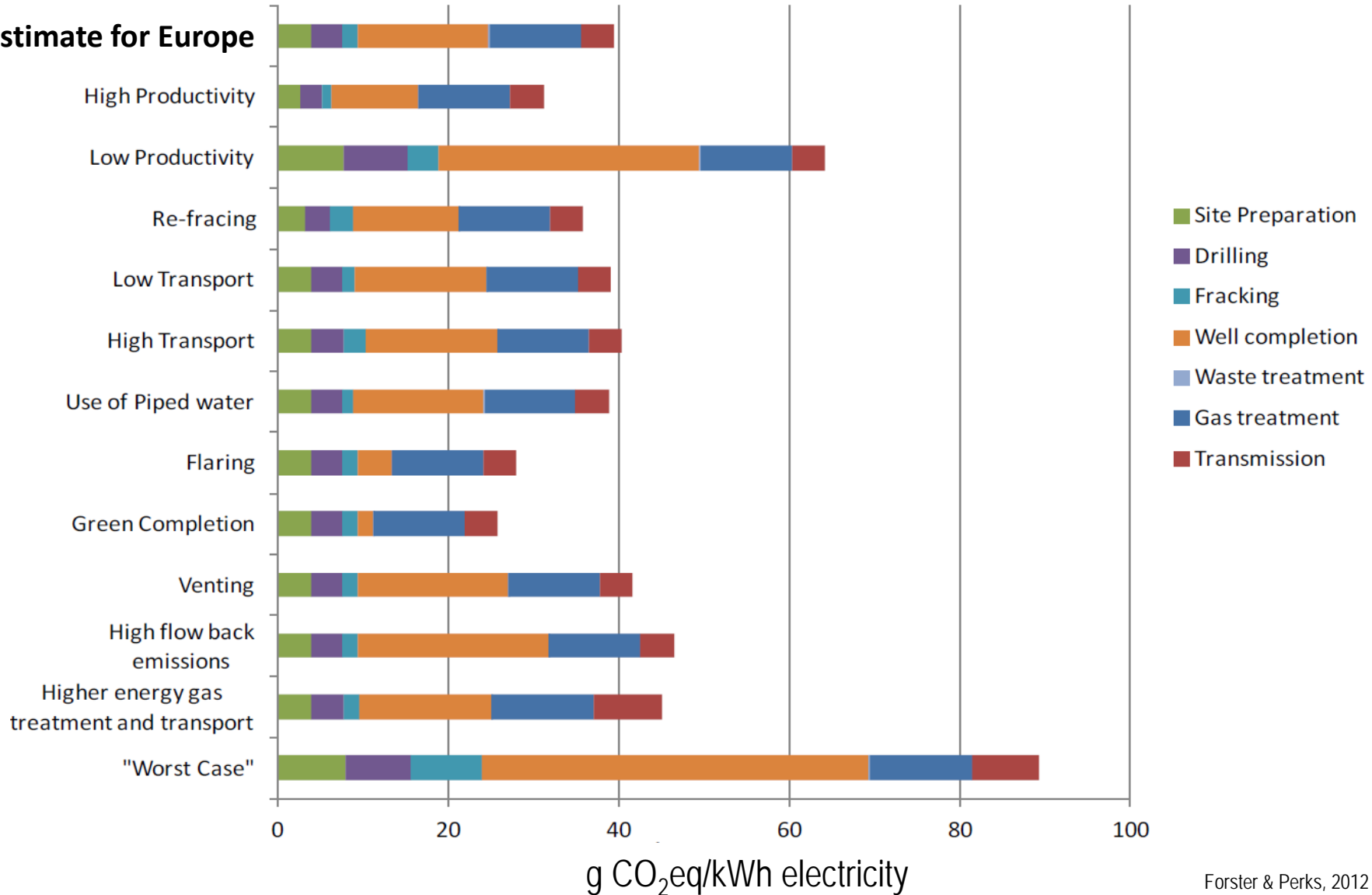
LCA results: GHG_{GWP100a} emissions



Electricity production from shale gas: pre-combustion stages

Best estimate for Europe

Sensitivities for different parameters



Forster & Perks, 2012