Life Cycle GHG Emissions from Conventional Natural Gas Power Generation: Systematic Review and Harmonization




InLCA XII

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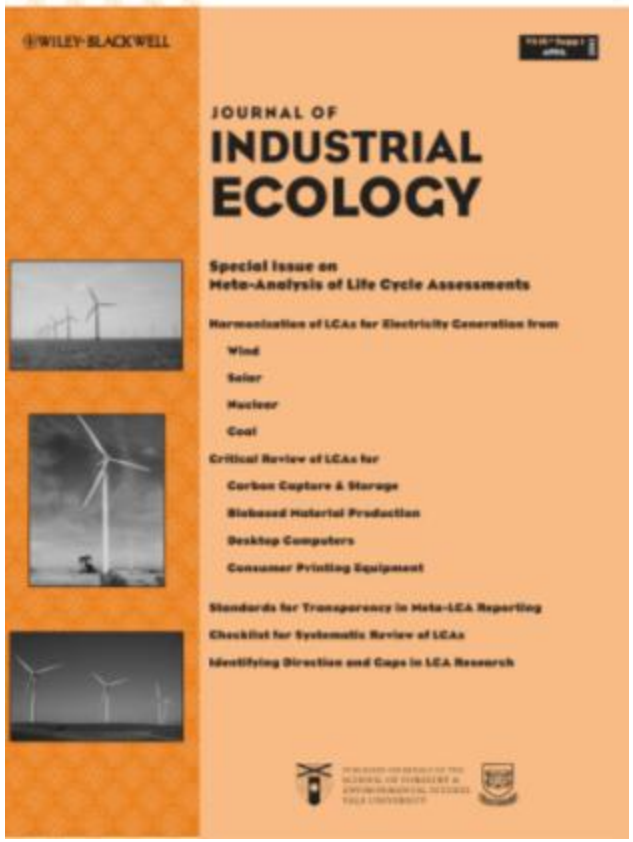
LCA Harmonization Project

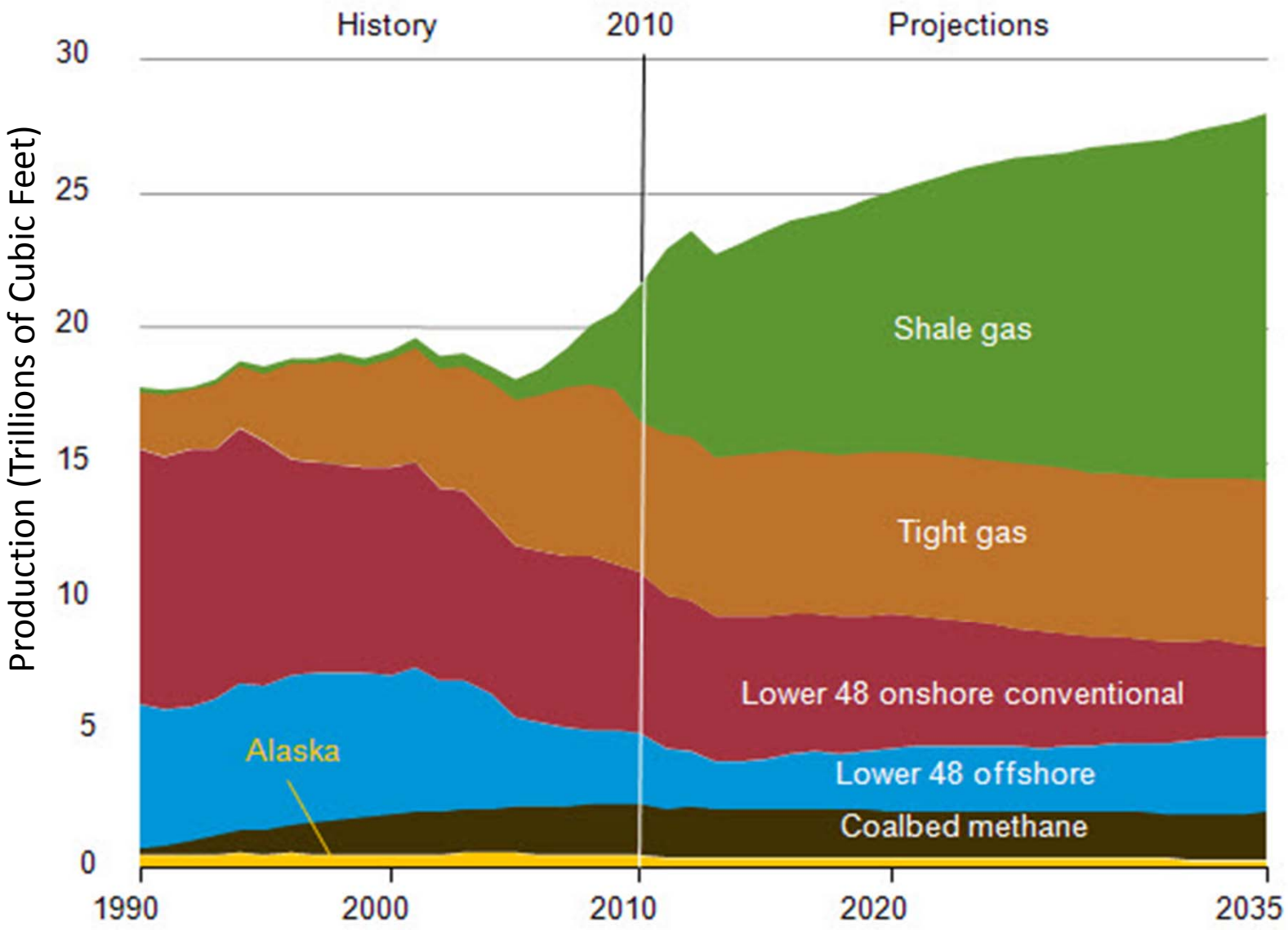
Six articles in special issue of *Journal of Industrial Ecology* on **Meta-Analysis of LCA** (May 2012)

- Coal
- Nuclear
- Wind
- Concentrating solar power
- Crystalline silicon PV
- Thin-film PV.

Key gap: Natural Gas.

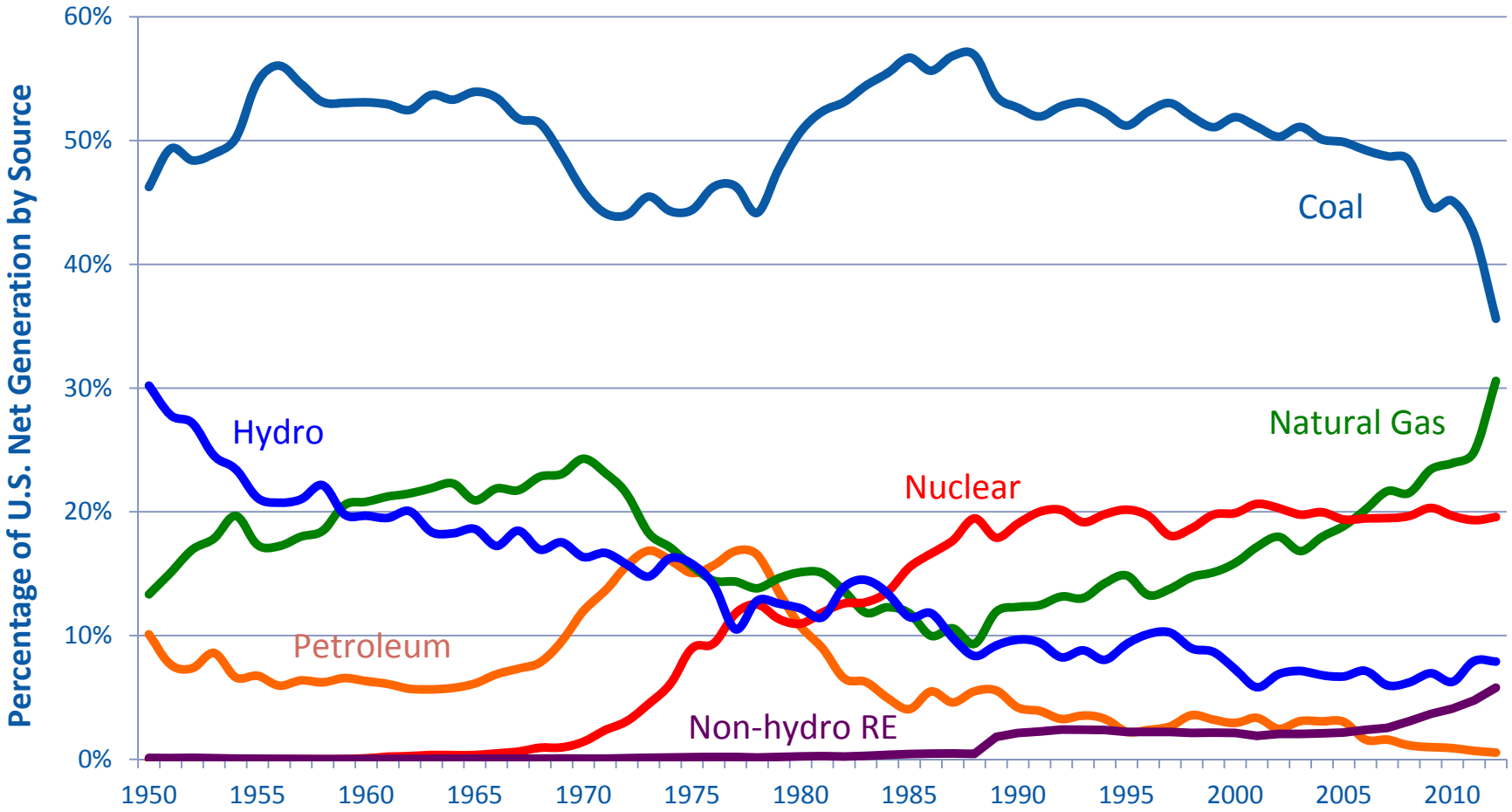


Importance of Natural Gas for Domestic Energy



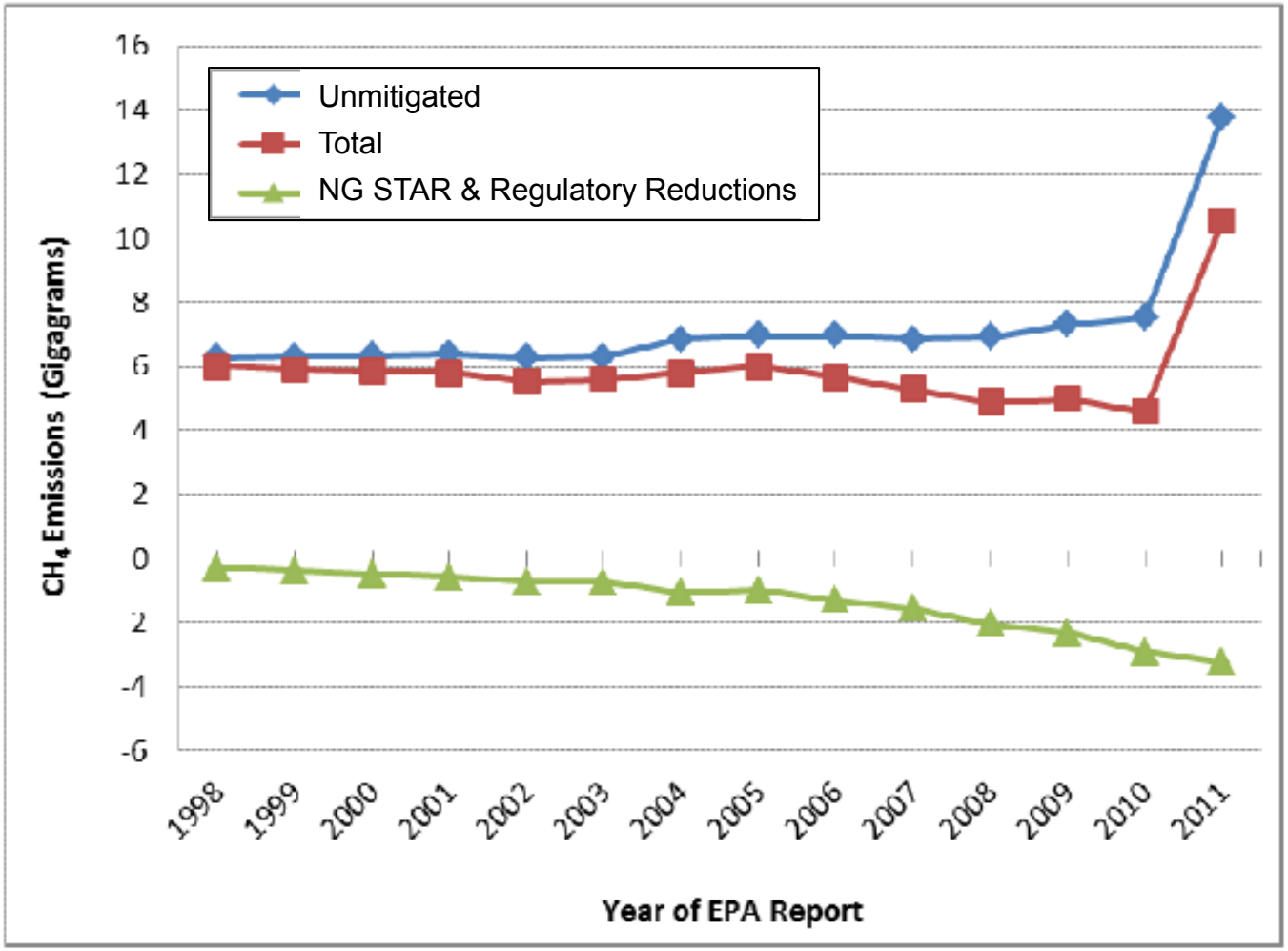
Source: EIA, *EIA Annual Energy Outlook*, 2012

Importance of Natural Gas: Electricity



Source: EIA, *Annual Energy Review*, October 2011; EIA, *Electric Power Monthly*, August 26, 2012. Data for 2012 includes generation through June.

NG Upstream Emissions Estimates



Source: Burnham et al. (2012)

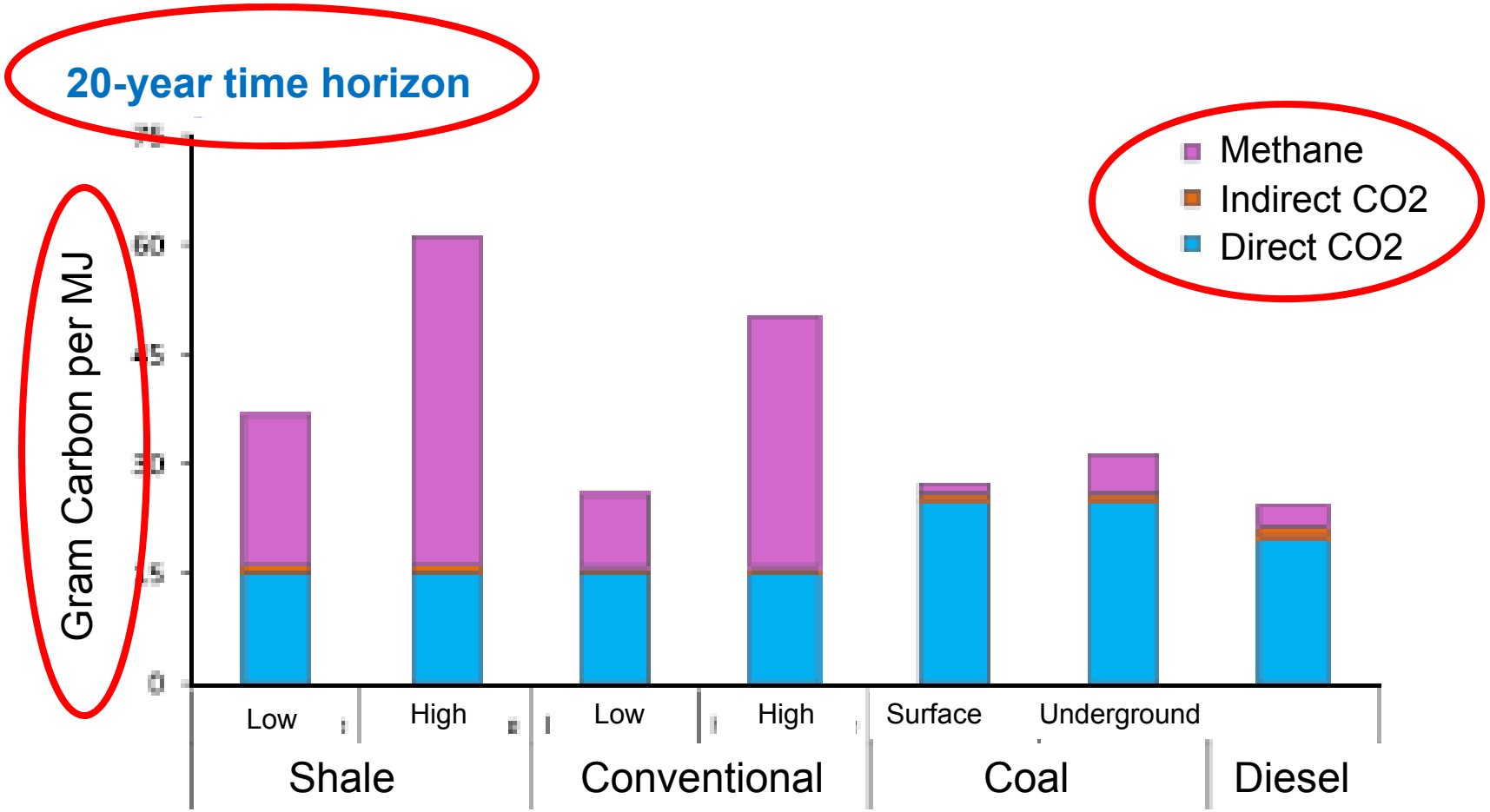
2011 vs. 2010: based on EPA Subpart W to U.S. GHG Inv.

- >2x production
- +10x liquids unloading (conv.)

Also:

- Completions
- Workovers
- Centrifugal compressors.

Importance of Harmonization: Case of Howarth et al. 2011



= elements requiring harmonization to make consistent comparisons across studies

Source: Howarth et al. (2011)

Literature Review Counts

Technology Category	References Reviewed	Passing the First Screen	Passing the Second Screen	Providing GHG Emissions Estimates
Biopower	369	162	84	52
Coal	273	192	110	52
Concentrating solar power	125	45	19	13
Geothermal	46	24	9	6
Hydro	89	45	11	11
Natural gas	261	165	85	43
Nuclear	249	196	64	32
Ocean energy	64	30	6	5
Oil	68	45	19	10
Photovoltaics	400	239	75	26
Wind	231	174	72	49
Totals	**2165**	**1309**	**546**	**296**
% of total reviewed		**60%**	**25%**	**14%**
% of those passing 1st screen			**42%**	**23%**
% of those passing 2nd screen				**54%**

Note: Some double counting is inherent in the Totals given that some references investigate more than one technology. In addition, the counts represent progress to-date and could differ from final results once published.

Harmonization Steps

System Harmonization

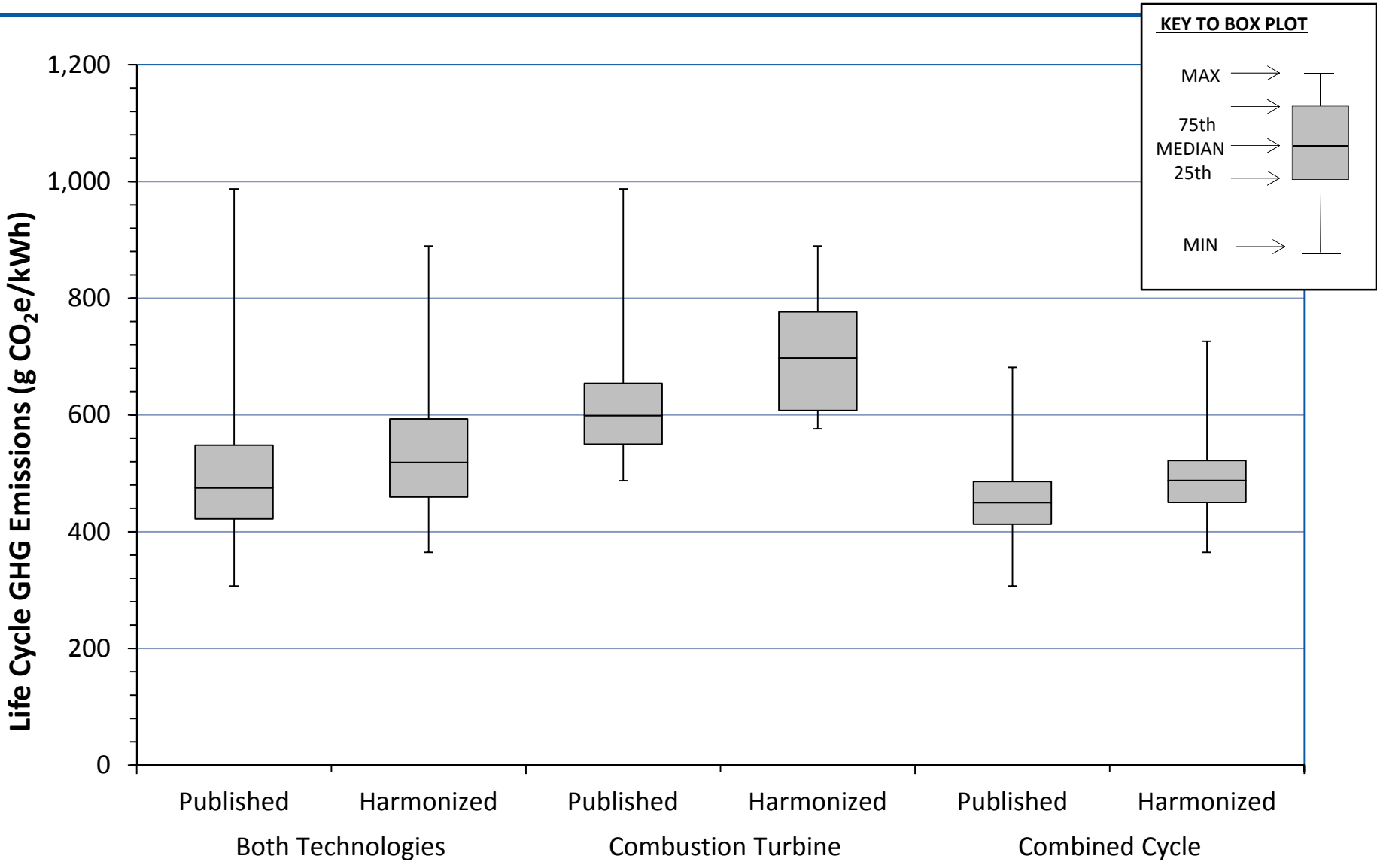
- GWP (global warming potentials)
  - IPCC 2007 values, 100-year time horizon
  - CH_4 – 25 g CO_2e/g CH_4
- Functional unit to kWh generated
  - Removed T&D losses
- Include power plant upstream and downstream emissions
  - Construction, power plant materials, decommissioning (~1 g CO_2e/kWh)
- Include embodied GHG emissions in well pre-production
  - Upstream (embodied) emissions for drilling equipment, concrete, steel, gravel, asphalt, land clearing/disturbance (small)
- Include liquids unloading
  - All pre-2011 (EPA subpart W) didn't account for it or included only 10% of updated value
  - Depends on assumed EUR, well lifetime, emissions reductions
  - ~27 g CO_2e/kWh central estimate.

Harmonization (cont'd)

Technical harmonization

- Power plant efficiency
  - 51% for combined cycle
  - 33% for combustion turbine
- Power plant lifetime and capacity factor
  - Small impact – only affects upstream/downstream amortization
- Natural gas heating value
  - Small impact – not often reported and low variability.

Harmonization (Preliminary) Results



Estimates:	69	18	51
References:	43	7	43

Harmonization (Preliminary) Statistics

Conventional NG Life Cycle GHG Emissions (g CO_2e/kWh)

Technology	Median	Mean	IQR
Both technologies	520	550	134
Combined cycle	490	500	72
Combustion turbine	700	710	170

~20% of life cycle GHGs from fuel cycle

~80% from combustion (operation).

Harmonization Caveats and Responses

For some users, only system harmonization is appropriate

- For others, results after all steps of harmonization is useful
- Transparent results and methods

Results express variability around a modern reference system

- Outline approaches to adjust our results to other assumptions

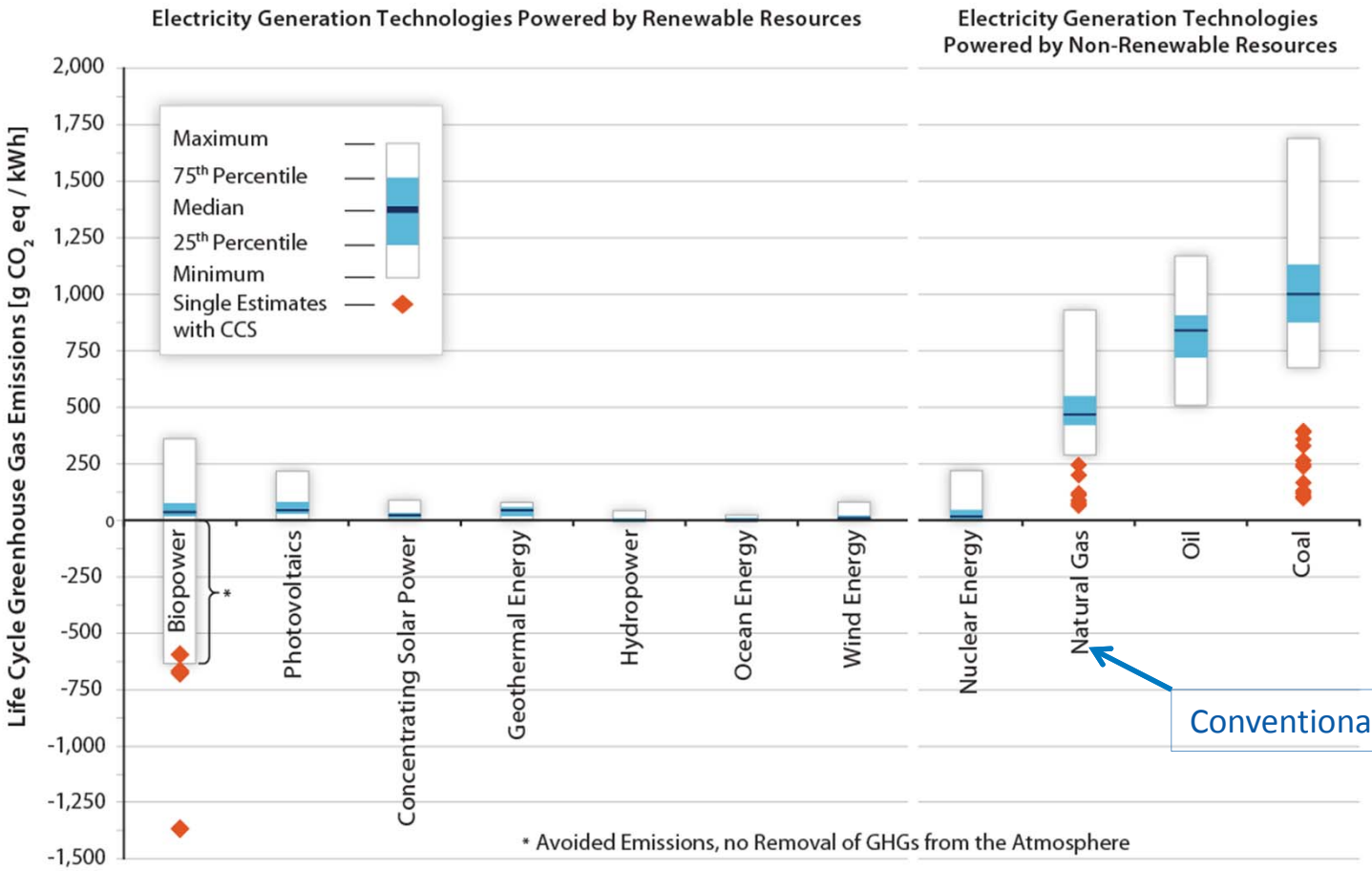
Not a true sensitivity analysis

- Most effective harmonization steps help identify influential parameters (for NG → efficiency)

Precision vs. accuracy

- Accuracy still an issue for NG: missing factors, new science
- Recommended research.

NG in Context (Published Estimates <2011)



IPCC SRREN SPM Fig 8

Conventional only

	Biopower	Photovoltaics	Concentrating Solar Power	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Nuclear Energy	Natural Gas	Oil	Coal
Count of Estimates	222(+4)	124	42	8	28	10	126	125	83(+7)	24	169(+12)
Count of References	52(+0)	26	13	6	11	5	49	32	36(+4)	10	50(+10)

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Concluding Thoughts

- Natural gas appears to have lower GHG emissions than coal on average
  - Overlapping range at worst NG efficiency or high methane leakage
  - Coal with CCS appears lower
- New measurements of fuel-cycle GHG emissions are needed to improve understanding of magnitude and variability and for comparison to other technologies.
- Comparison to unconventional NG (e.g., shale gas) is the subject of other studies
  - See JISEA NG study (www.jisea.org) which evaluates life cycle GHG emissions for electricity generated using Barnett shale gas produced in 2009
  - Harmonization of shale gas LCAs in preparation

Acknowledgements and Pointers

Funding from US DOE / EERE

Special Issue on Meta-Analysis of LCA:

http://jie.yale.edu/LCA-meta-analysis

NG article pending response to peer review comments.

NREL LCA Harmonization project:

www.nrel.gov/harmonization

Data visualization and download:

en.openei.org/LCA.