Indirect Impacts of Alternative Electricity Penetration and the Growing Importance of a Life Cycle Perspective

Joe Marriott[1], Jeremie Hakian[2], Tim Skone[3]

[1] Booz Allen Hamilton, [2] SCS Global, [3] Strategic Energy Analysis and Planning, NETL

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U.S. DEPARTMENT OF ENERGY | National Energy Technology Laboratory

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This work came out of discussions regarding co-product management for large-scale energy systems

- **Systems like a coal plant with carbon capture connected to CO_2-EOR co-produce large amounts of fuels and power with no obvious – or even correct – way to allocate environmental burdens among them**

- **In previous work, we showed why system expansion with displacement is a reasonable choice despite uncertainty regarding the displacement credit**
  - That uncertainty *must* be quantified, or at least bounded, and displayed as part of the answer

Choosing a product to displace is not easy

- **Your choice of displaced product can:**
  - Dramatically change the footprint of your product of interest
  - Be gamed by unscrupulous practitioners
  - Be picked apart by displeased critics

- **In the example of a fuels plant which co-produces electricity, deciding what gets displaced in the near term is complicated enough**
  - Because of the lack of better information, most practitioners will choose to displace either national or regional grid electricity
  - But plant infrastructure will likely last for 60-80 years: what is being displaced in year 80 will be very different from what is displaced in first year of operation

What is the future mix of power generation?

- **We hypothesized that it would look very different, much in the same way that today's mix looks dissimilar from the electricity mix of 60 years ago**
  - The life cycle GHG emissions per unit electricity generated, and therefore the displacement credit you would get would also be different
- **A secondary hypothesis was that as the direct GHG intensity changed (and presumably decreased), the relative importance of indirect emissions sources would increase**

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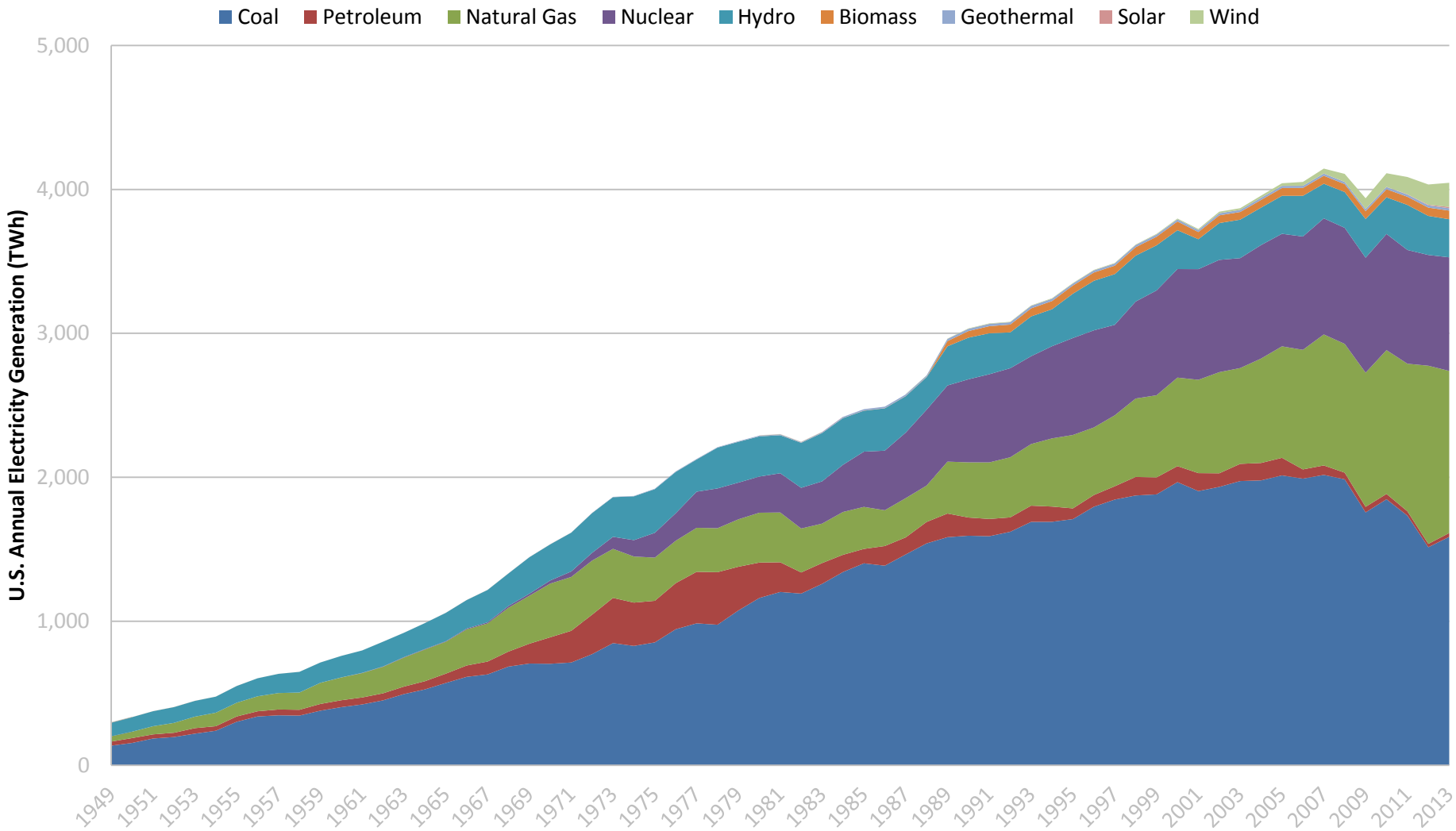
Definitions of direct and indirect emissions

- **In the past, only stack emissions mattered, and justifiably so, as they accounted for the vast majority of emissions and environmental impact**
  - LCA strives to change that perspective and include all sources of emissions related to the production of the product of interest
- **Despite the usefulness of talking about inventory items which are not stack emissions, there doesn't seem to be an agreed-upon term for them**
  - "upstream/downstream", "life cycle adders", "facility and non-facility", "supply/value chain", etc.
- **For this exercise, we define anything that's a GHG emission from primary feedstock combustion (a stack emission) as direct emissions**
  - Think of it as a ca. 1970s or 80s air regulation boundary
  - Indirect emissions, then are the full life cycle value less any direct emissions per definition above
- **This is also the general public views alternative or renewable power generation: nuclear, solar, wind, and hydro are considered to be emissions-free**

Examples of indirect emissions for a coal-fired power plant:

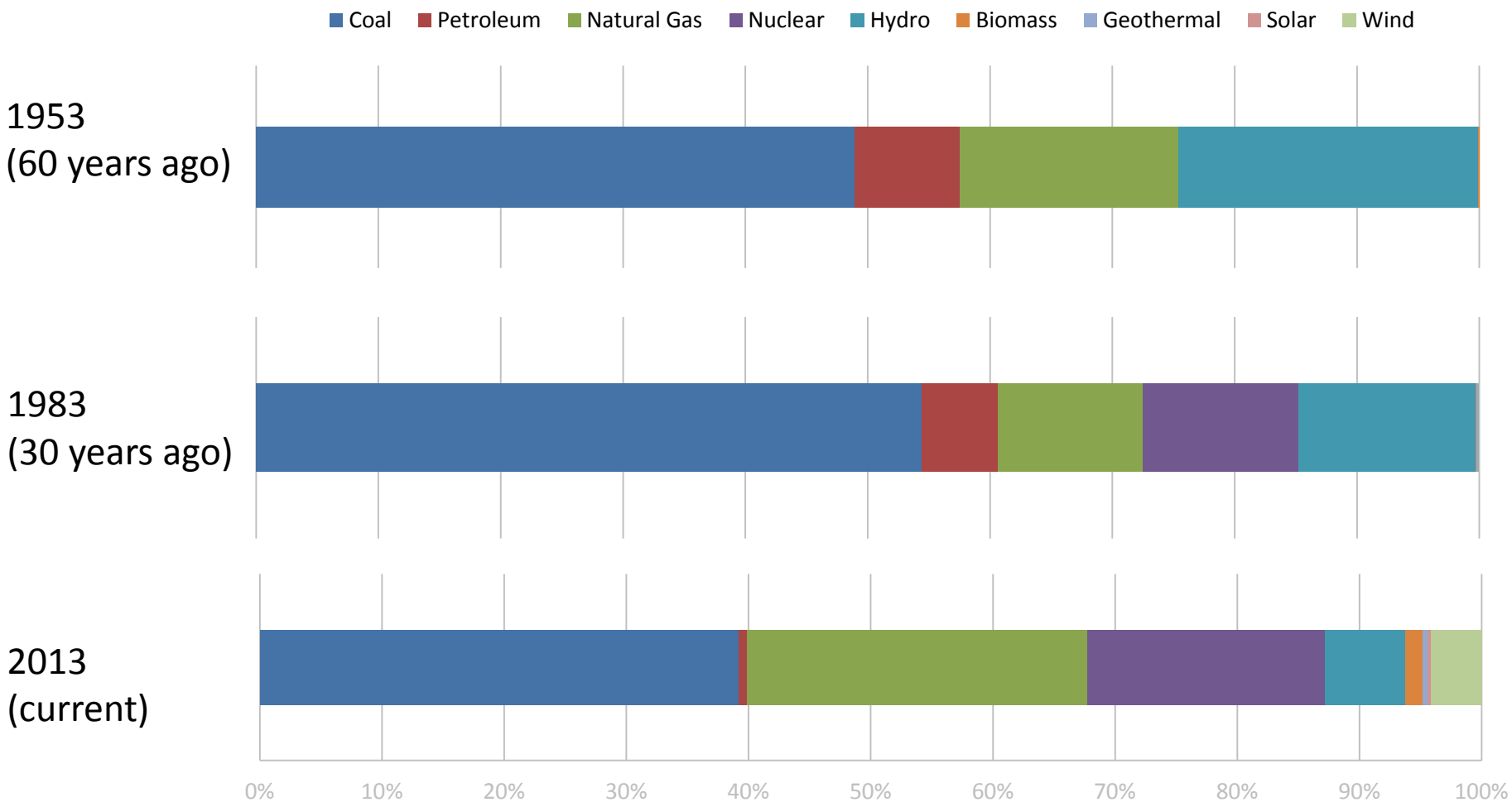
- Power plant construction
- Equipment manufacturing
- (Turbines, boilers, pipes)
- Secondary feedstock production (ammonia, limestone, amine, etc.)
- On-site operations (vehicles, lights, etc.)
- Coal mining, transport and processing
- Waste hauling and management
- Transmission infrastructure

For 60 years, U.S. power generation dominated by fuels with large *direct* impacts



EIA, 2014

Recent years have been characterized by the growth of natural gas and alternative generation



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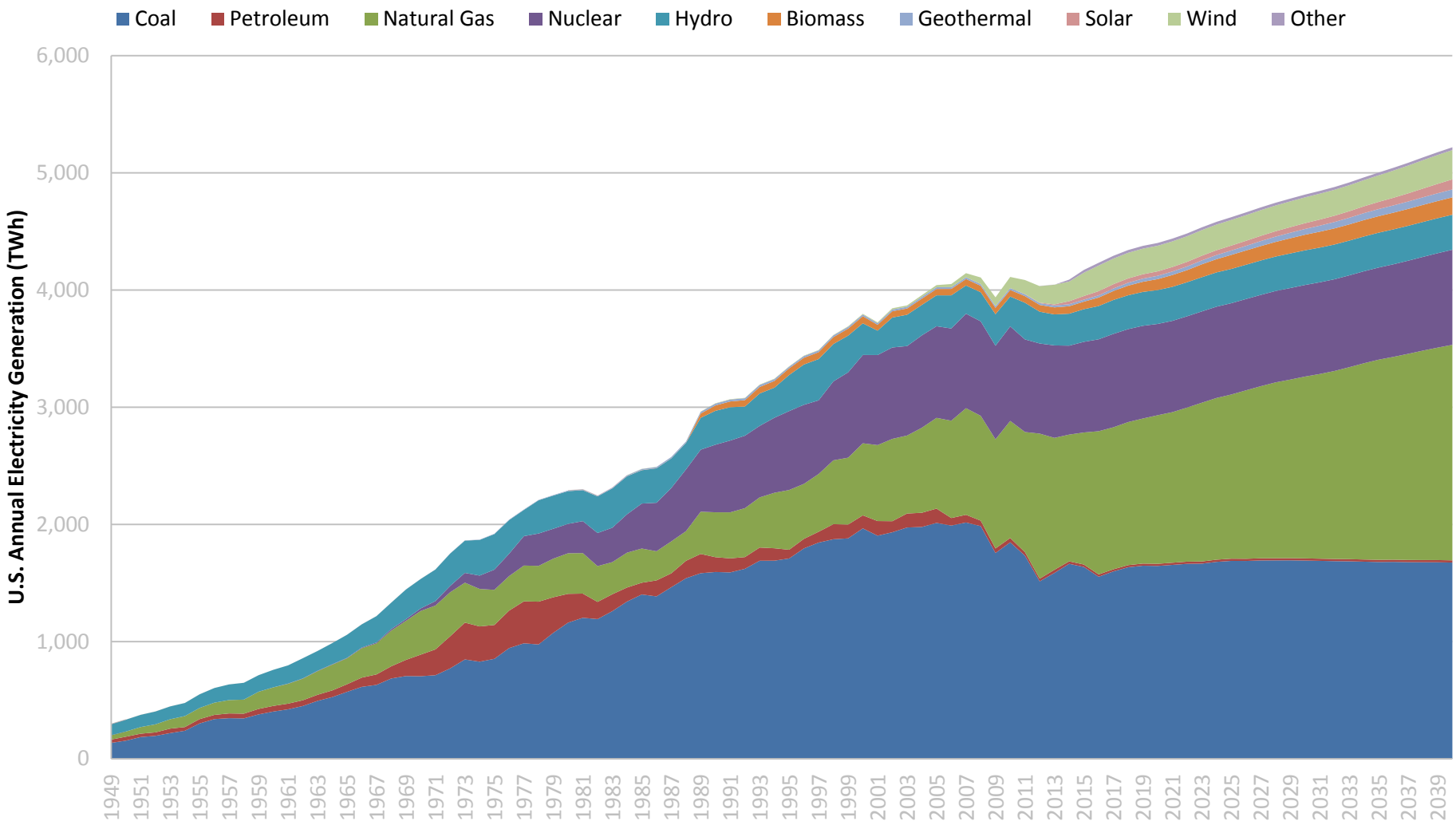
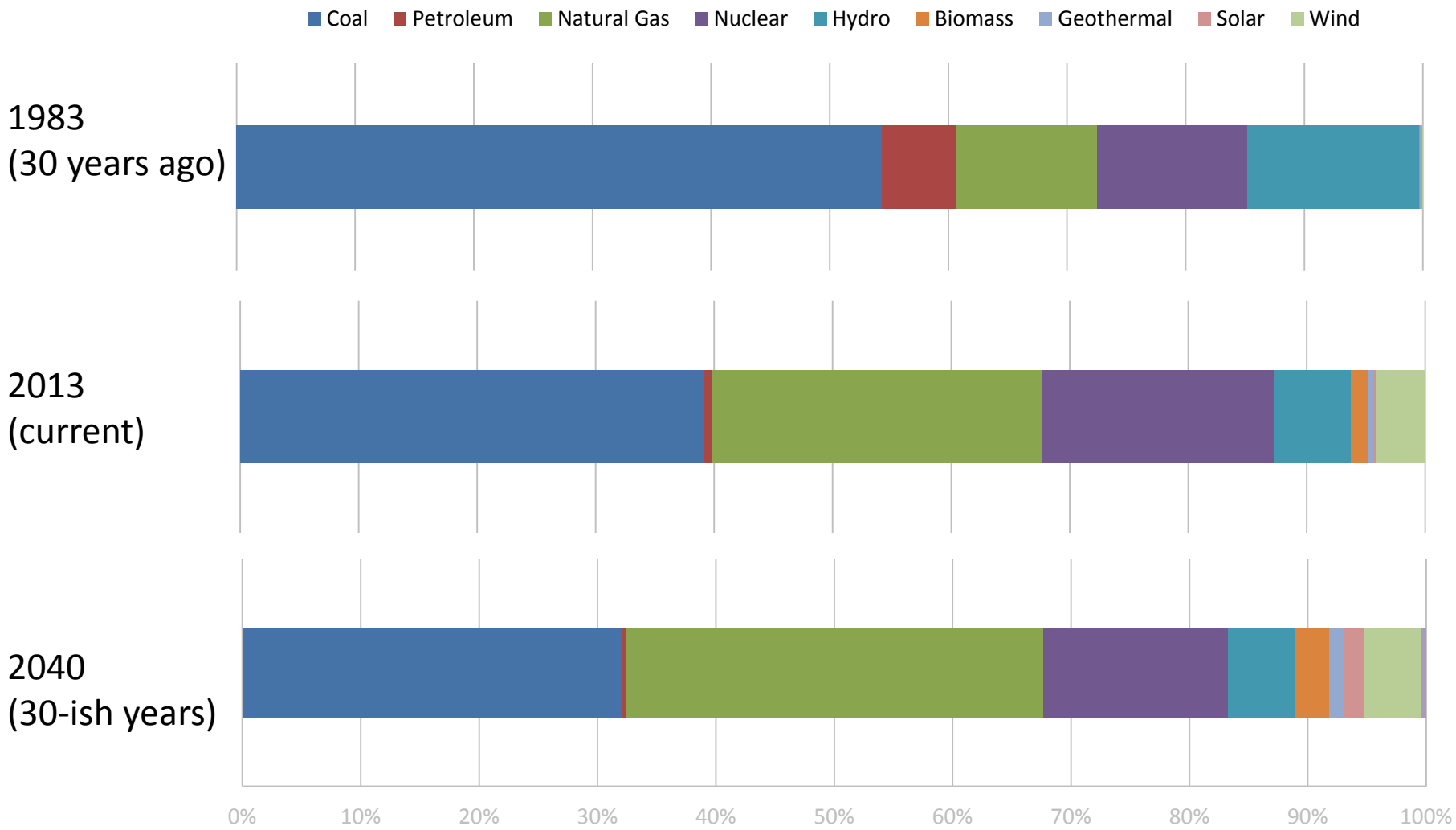
EIA Reference Case forecasts continued dominance of fossil fuels through 2040



EIA 2014

With supply changes normalized, shifts are more apparent, especially coal-to-gas



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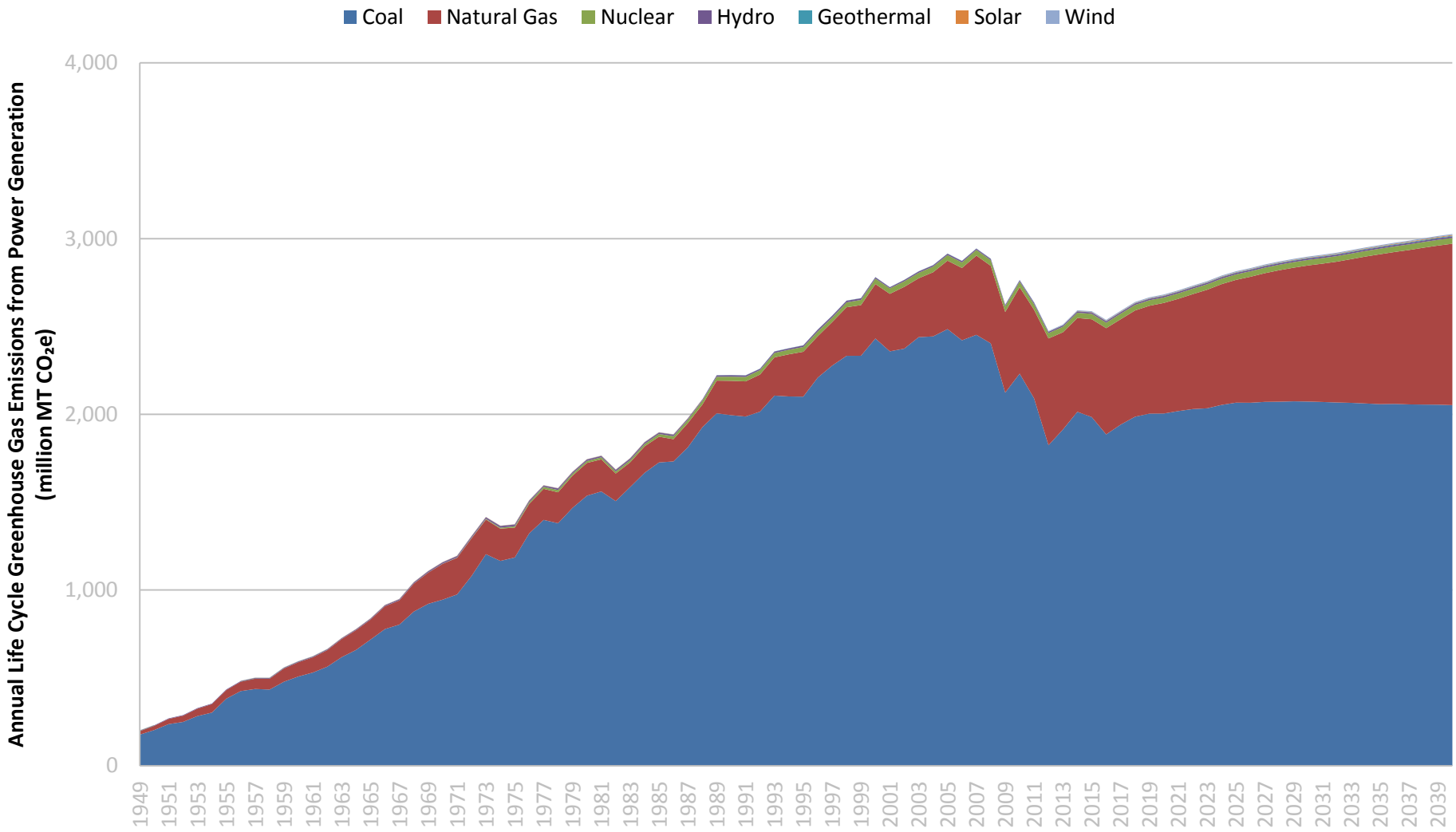
Life cycle GHGs for power generation, split into direct and indirect components

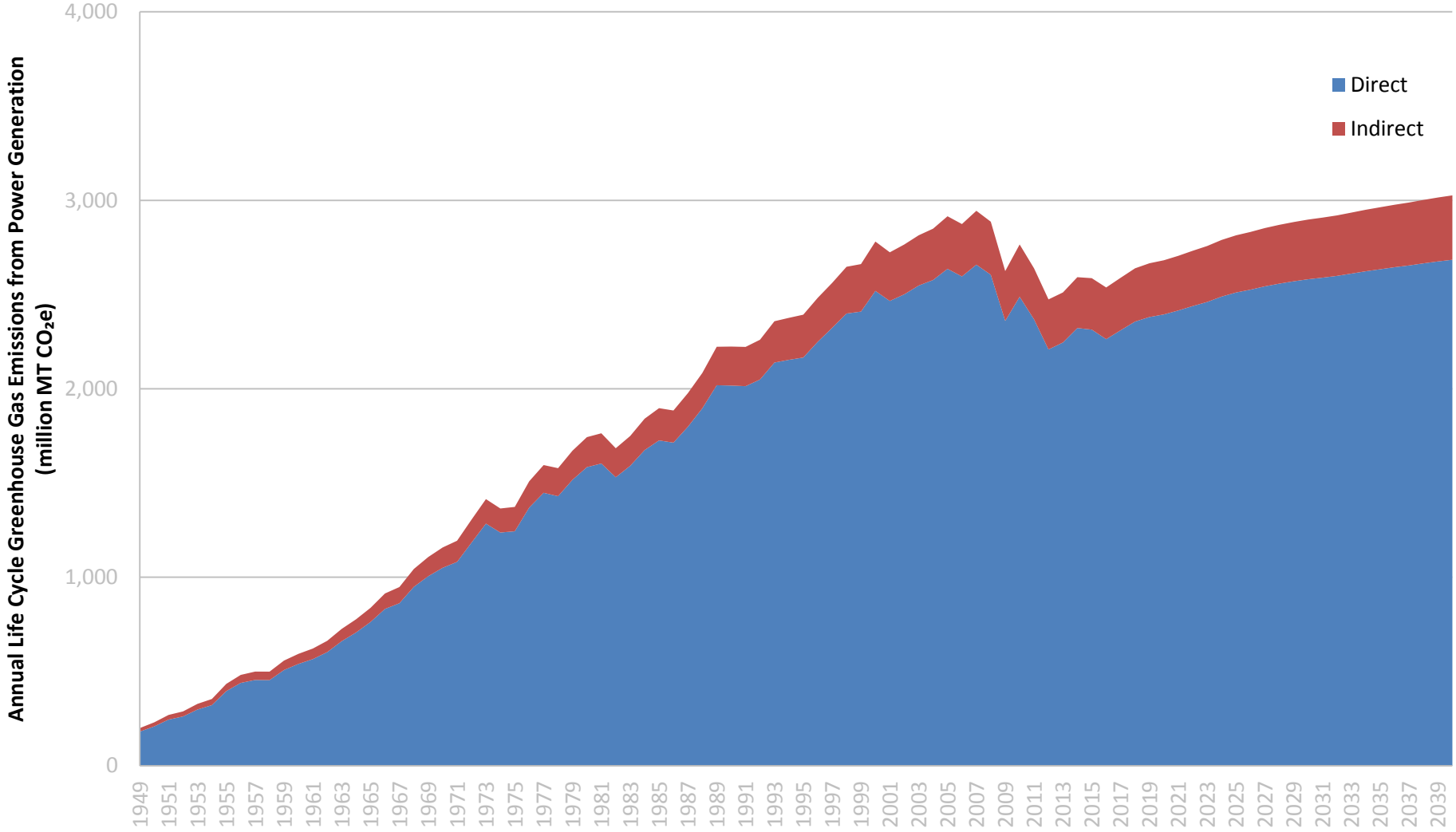
Power Plant	Direct GHG Emissions (g CO_2e/kWh)	Indirect GHG Emissions (g CO_2e/kWh)	Life Cycle GHG Emissions (g CO_2e/kWh)	Direct Share (%)	Indirect Share (%)
U.S. Fleet Coal	1,095.4	85.3	1,180.7	93%	7%
SCPC	866.1	98.5	964.6	90%	10%
SCPC w/ CCS	137.1	140.1	277.2	49%	51%
U.S. Fleet Natural Gas	408.8	72.3	481.2	85%	15%
NGCC	392.9	57.4	450.3	87%	13%
NGCC w/ CCS	56.5	85.8	142.3	40%	60%
Gas Turbine	600.6	111.2	711.8	84%	16%
U.S. Fleet Nuclear	0.0	38.8	38.8	0%	100%
Adv. (Gen III+) Nuclear	0.0	9.4	9.4	0%	100%
Hydro	0.0	28.2	28.2	0%	100%
Geothermal	0.0	57.8	57.8	0%	100%
Solar	0.0	47.3	47.3	0%	100%
Wind	0.0	21.4	21.4	0%	100%
Offshore Wind	0.0	28.9	28.9	0%	100%

Historic and forecasted GHG emissions from power generation are from fossil fuel combustion

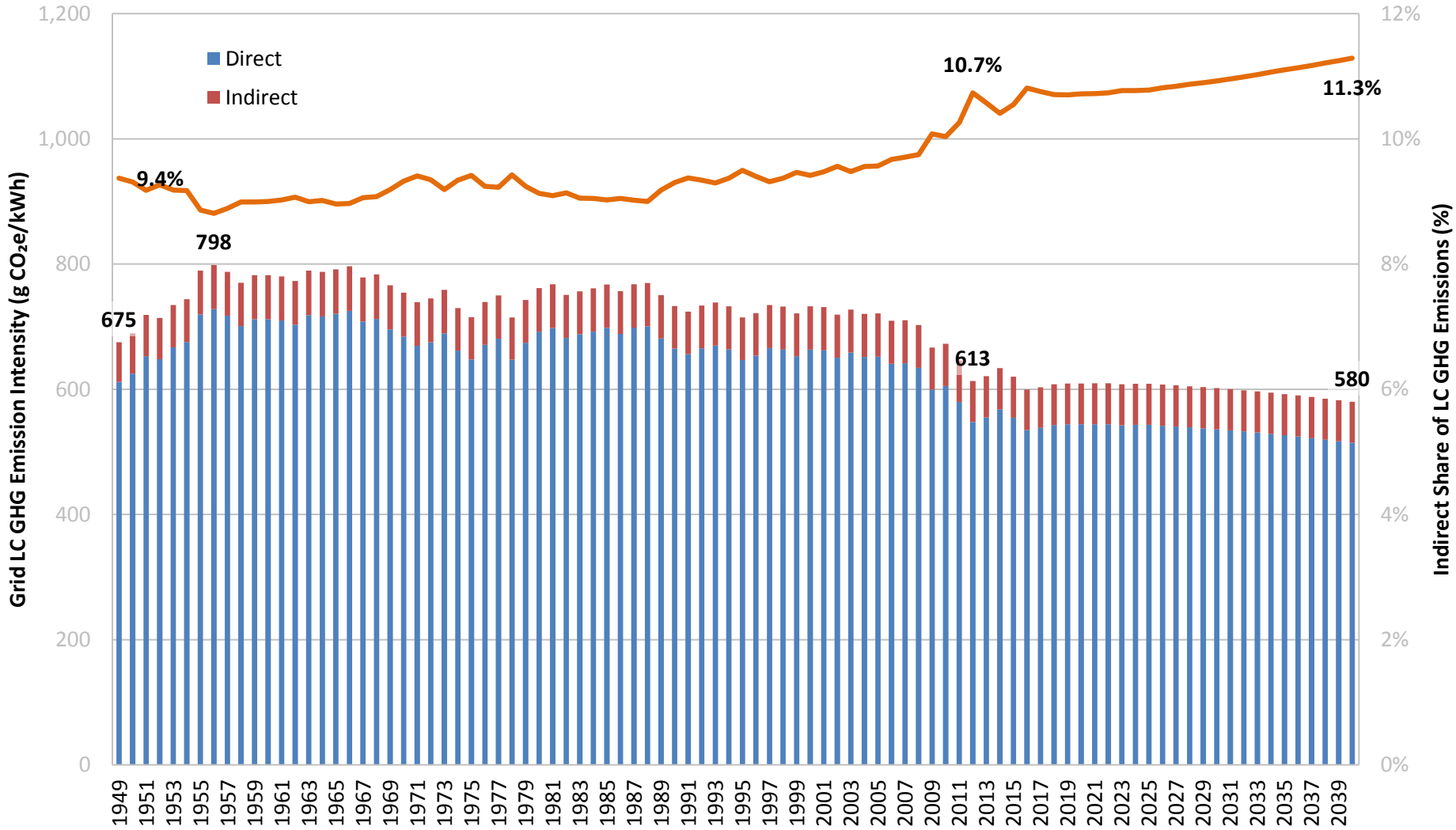


EIA 2014, NETL 2012-2014

Parse the same annual GHG emissions another way: direct and indirect



Grid LC GHG intensity is surprising robust to changes in the Ref. Case forecast

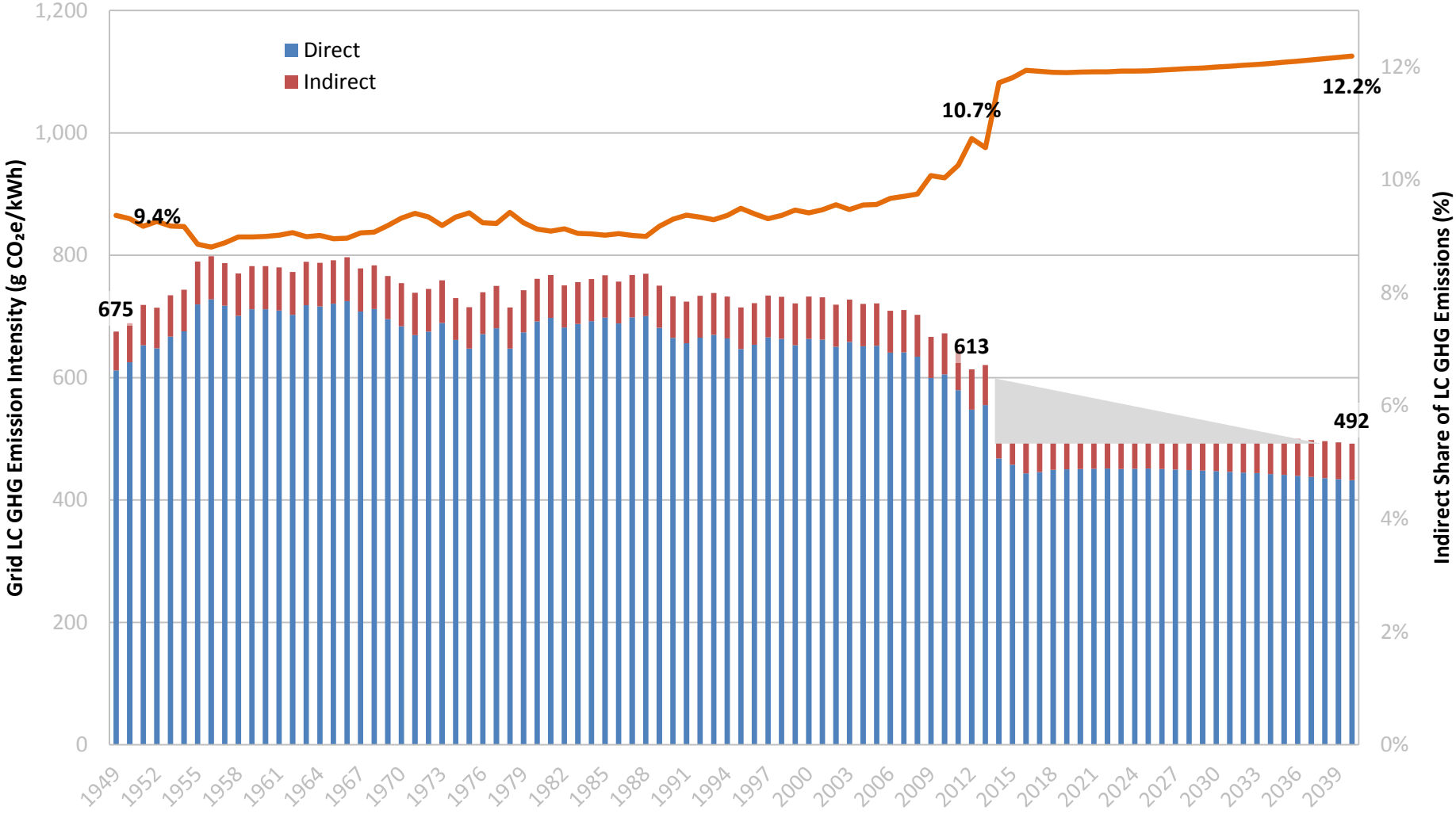


Grid LC GHG intensity is surprising robust to changes in the Ref. Case forecast

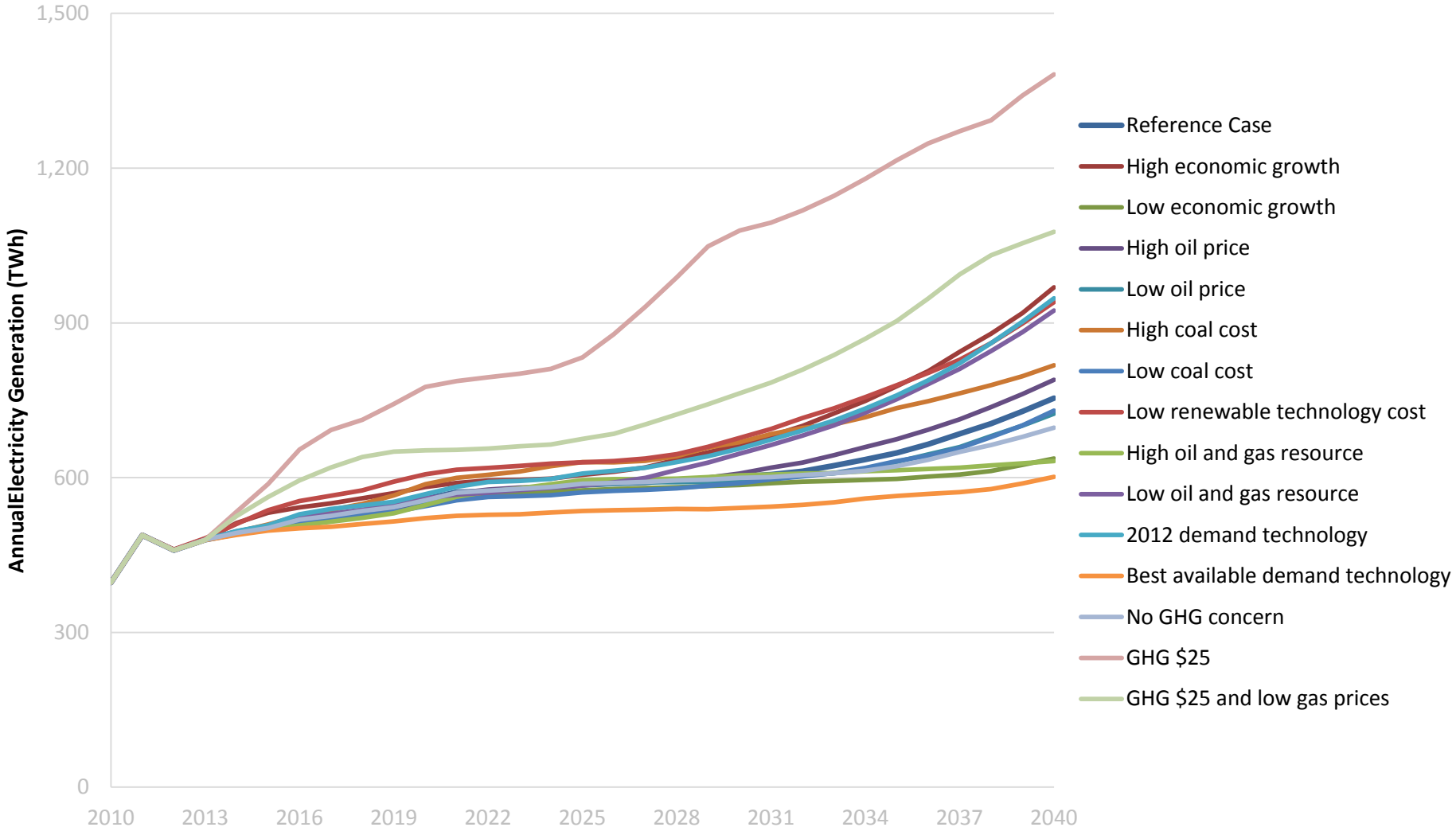
- **The grid LC GHG emission per unit of electricity generated has only decreased by about 9% in over 60 years, and is forecasted to change only 5% in the next 30**
- **Contribution of indirect emissions (the value we as practioners bring to energy analysis) has skyrocketed 14% since 1949; this jumps an additional 8% by 2040**

Year	LC GHGs (g CO_2e/kwh)	Indirect Share (%)
1949	675	9.4%
2013	613	10.7%
2040	580	11.3%

Reference Case forecast, with future generation replaced by "advanced" technology

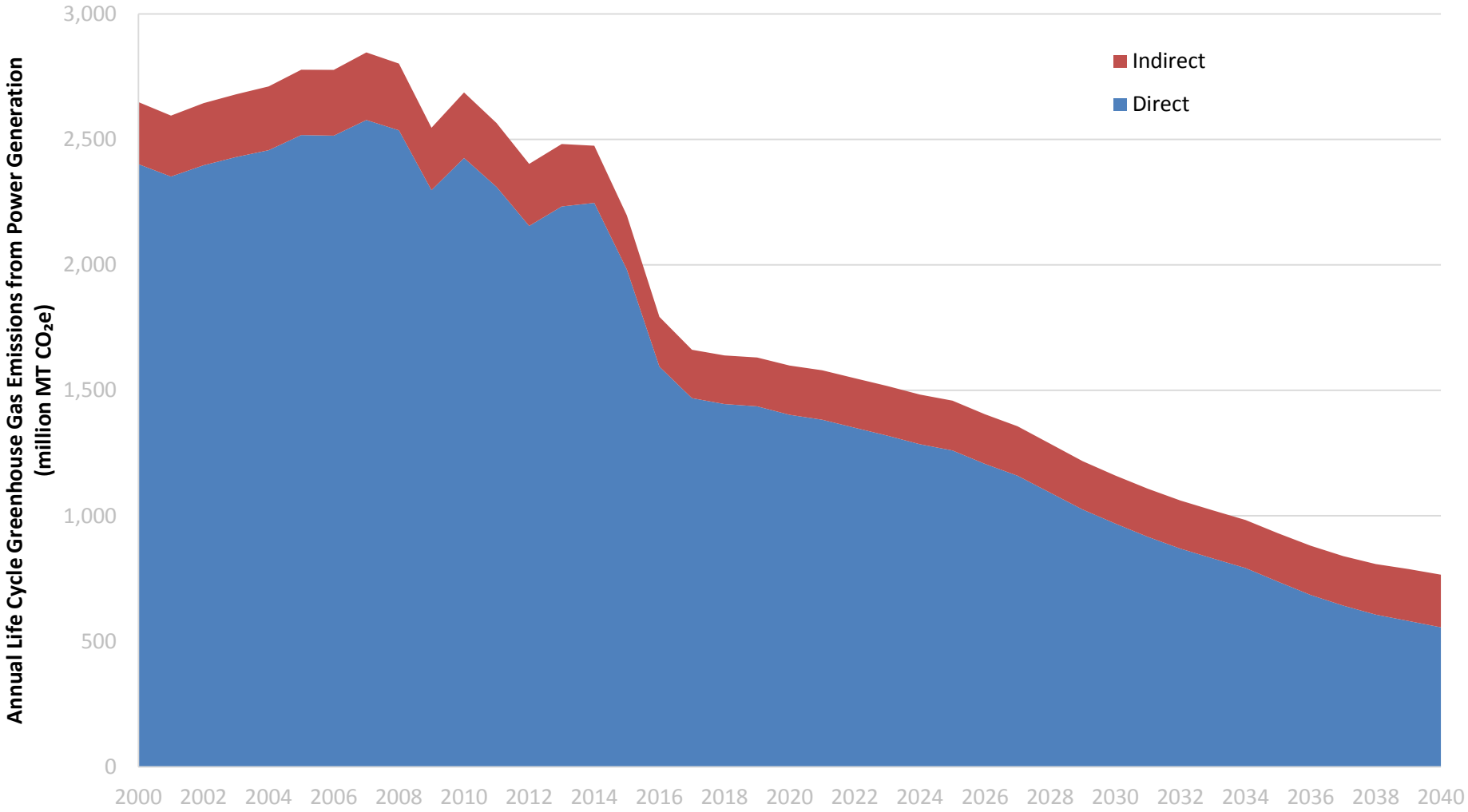


AEO has a wide variety of cases; the reference case has relatively low renewable penetration



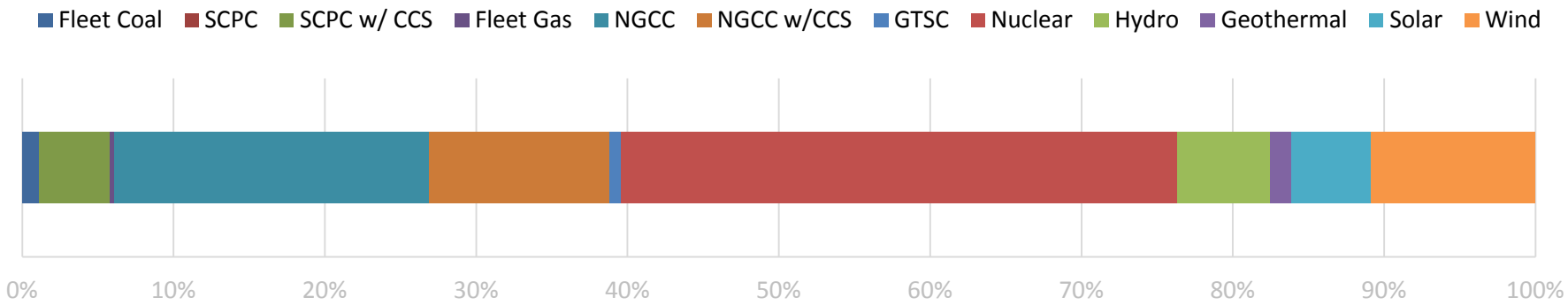
EIA AEO 2014

Example: Annual GHG forecast with a $25/MT CO_2e cost imposed in 2015



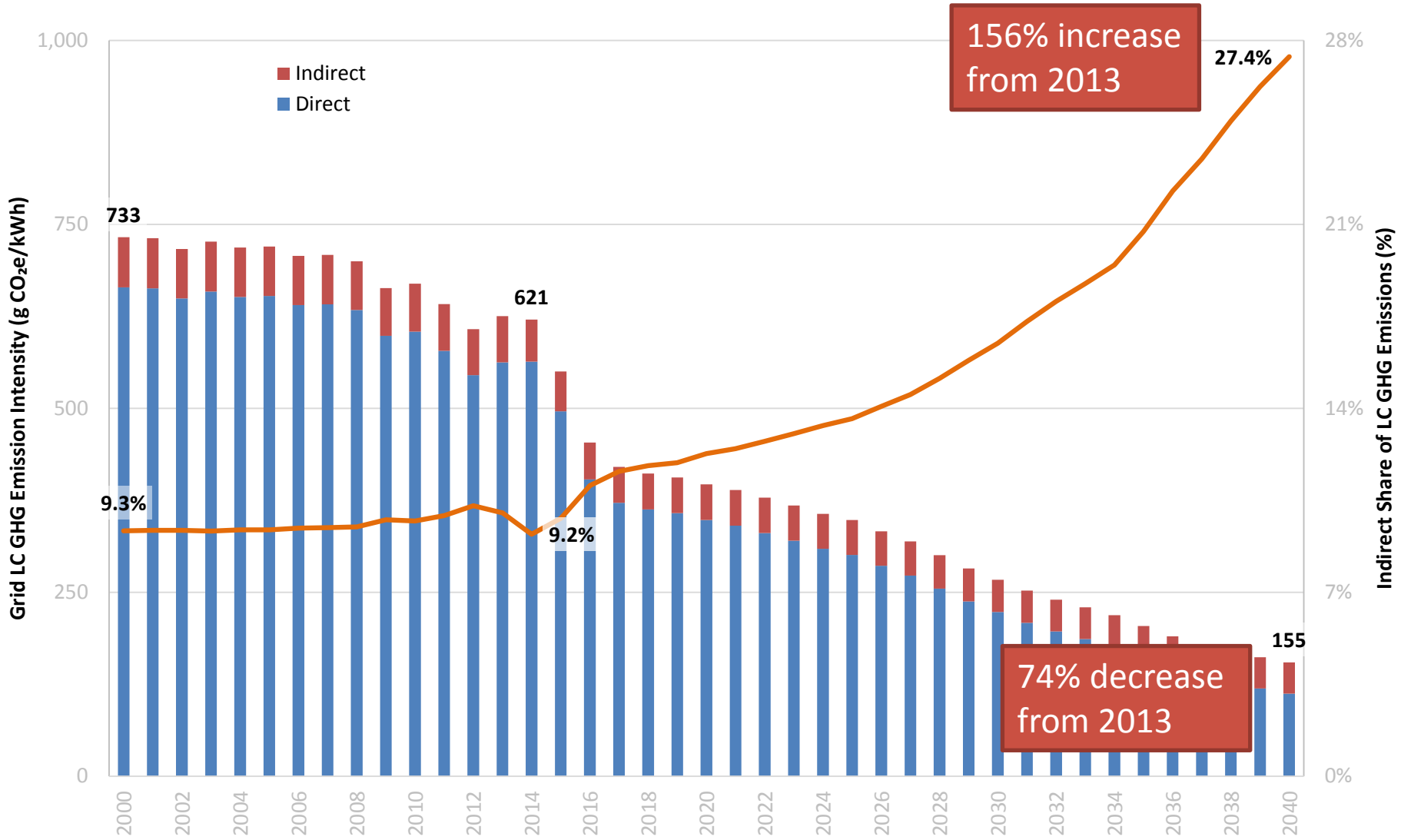
EIA 2014, NETL 2012-2014

The 2040 fleet at $25/tonne carbon looks *very* different from today



- Virtually the entire current coal and gas fleets have been retired
- Carbon capture is in place in large amounts on new gas plants and smaller amounts on new coal
- Nuclear has expanded, as have all types of renewables

Under GHG25, carbon intensity and the importance of indirect impacts have both changed a lot by 2040



Conclusions

- **Grid GHG intensity changes slowly over time, likely due to the relatively slow turnover of capacity and relatively small size of most new generation**
  - The future is highly uncertain; it is possible that more rapid shifts could occur given drastic policy actions
- **In general, GHG credits taken for co-produced electricity will be going down in the future, increasing the GHG footprints of products claiming them**
  - Care should be taken to quantify the range of possibilities
- **Importance of a life cycle perspective is increasing**
  - As GHG intensity goes down economy-wide, improvement needs to occur on other metrics
  - Relative contribution of non-obvious indirect impacts increases

Contact Us

Timothy J. Skone, P.E.

Senior Environmental Engineer • Strategic Energy Analysis and Planning Division • (412) 386-4495 • *timothy.skone@netl.doe.gov*

Joe Marriott, Ph.D.

Lead Associate • Booz Allen Hamilton • (412) 386-7557 • *joseph.marriott@contr.netl.doe.gov*

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