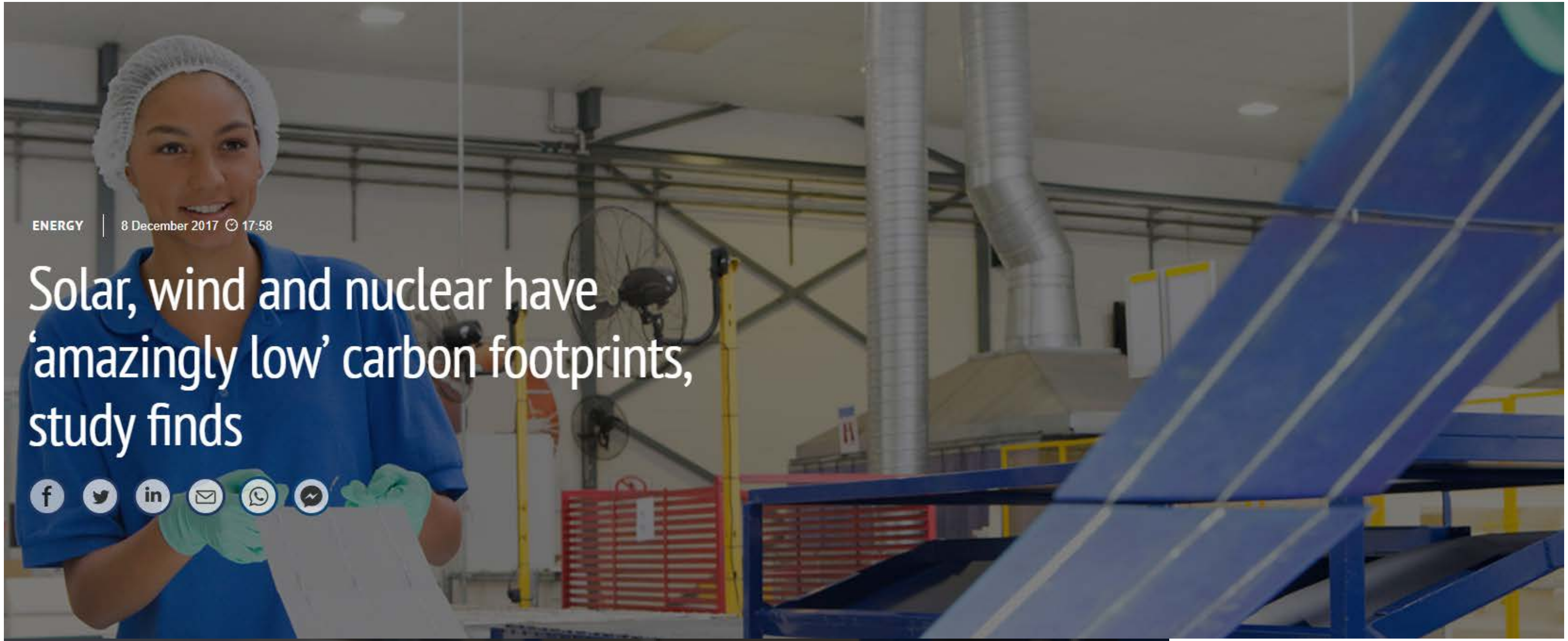
Life cycle greenhouse gas emissions of future power systems in the context of 2 °C

Anders Arvesen

Industrial Ecology Programme, Norwegian University of Science and Technology (NTNU)

Industrial Ecology Programme
Norwegian University of Science and Technology

“Amazingly low carbon footprints” (media coverage)



Technicians arranging solar cells to form solar panel on factory production line, South Africa.

Source: https://www.carbonbrief.org/solar-wind-nuclear-amazingly-low-carbon-footprints

Life cycle assessment (LCA)

LCA attributes emissions to products

1) Considering emissions over the life cycle
   - Production, use, end-of-life

2) Considering emissions in production networks
   - Resource extraction, manufacturing, etc.

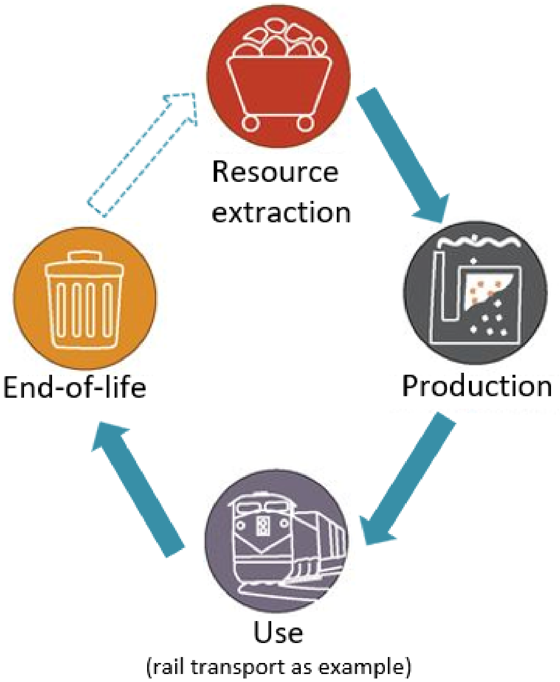


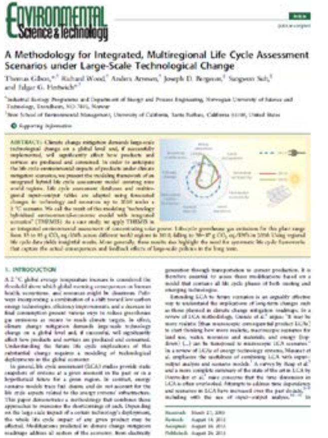
Figure: Adapted from Hellweg & Mila i Canals (2014)

LCA in a 2 °C context

- NTNU and partners has built a future-oriented LCA model, THEMIS
  - Incorporating future technological progress
- In the current work, coefficients derived from THEMIS were implemented into the energy scenario model REMIND
  - Operated by Potsdam Institute for Climate Impact Research
  - By default, REMIND does not systematically account for indirect, or life cycle, emissions


PNAS

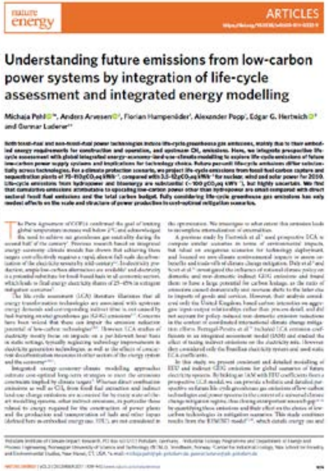
Integrated life-cycle assessment of electricity-supply scenarios confirms global environmental benefit of low-carbon technologies


Environmental Science & Technology

A Methodology for Integrated, Multiregional Life Cycle Assessment Scenarios under Large-Scale Technological Change


Environmental Modelling & Software

Deriving life cycle assessment coefficients for application in integrated assessment modelling


nature energy ARTICLES

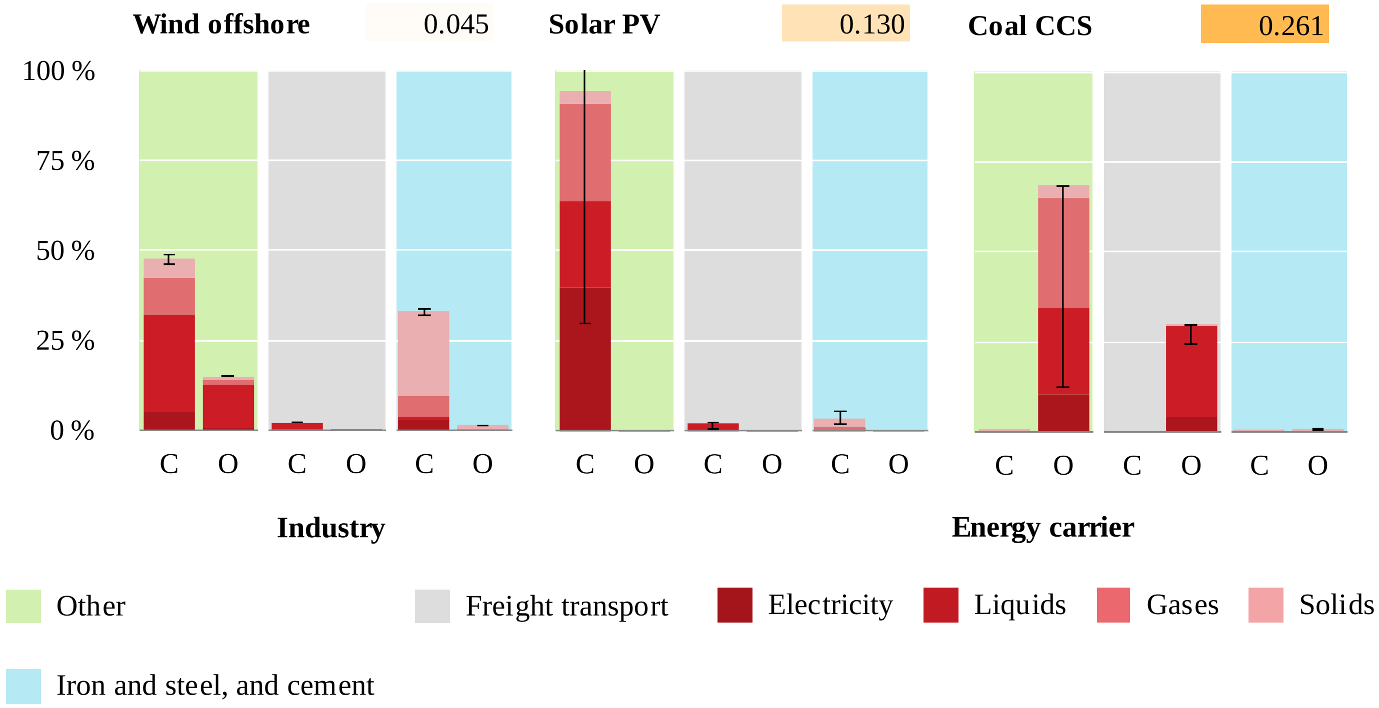
Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling

Introducing LCA in energy scenario modelling

- Step 1: Derive energy coefficients from LCA and organize the coefficients in a carefully chosen way
- Step 2: Implement the coefficients from Step 1 in the energy scenario model REMIND
- Step 3: Analyse life cycle emissions of global electricity supply in the context of 2 °C

- We capture technological progress and regional variation
  - In the energy technologies themselves
  - In the technologies used to supply energy and materials
- We achieve harmonization of parameter data

Example of LCA energy coefficients derived for use in scenario modelling (i.e., Step 1)

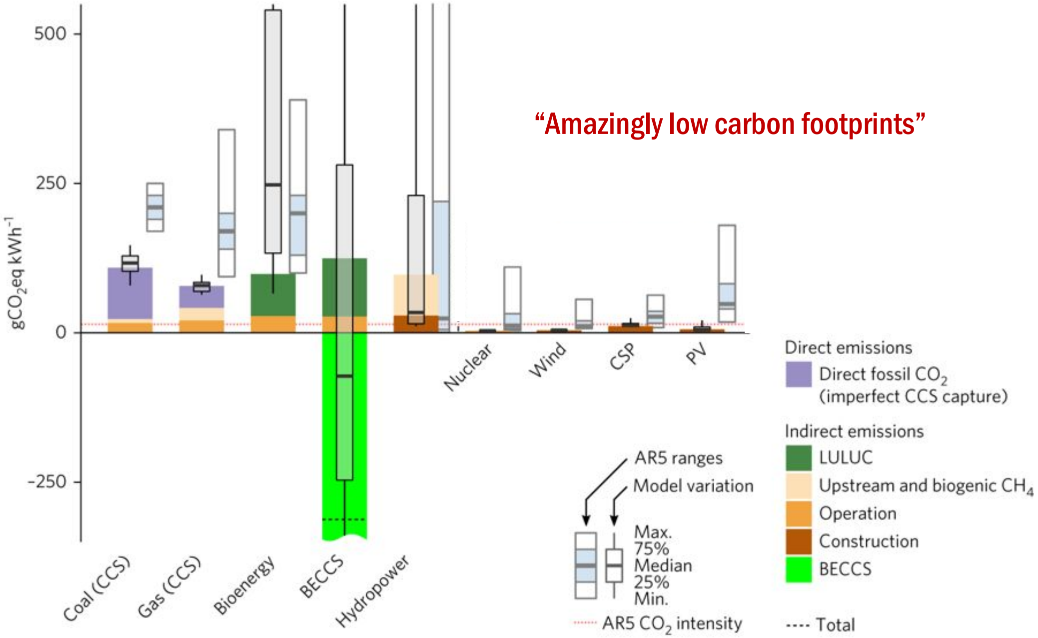


Distinguish:

- Construction (C) and operation (O)
- Energy carrier (stacked column categories)
- Industry (background colour)
- Region (not shown in figure)
- Year (not shown in figure)

Source: Arvesen et al. (2018)

Life cycle greenhouse gas emissions in 2050 in REMIND



"Amazingly low carbon footprints"

In a 2 °C world in 2050 (these are global averages):

- Nuclear, wind and solar PV: 4-6 g CO_2e kWh^{-1}
- Hydro and bioenergy: ~100 g CO_2e kWh^{-1} (very uncertain)
- Coal and gas with CO_2 capture: ~100 g CO_2e kWh^{-1}

Figure: Pehl et al. (2017)

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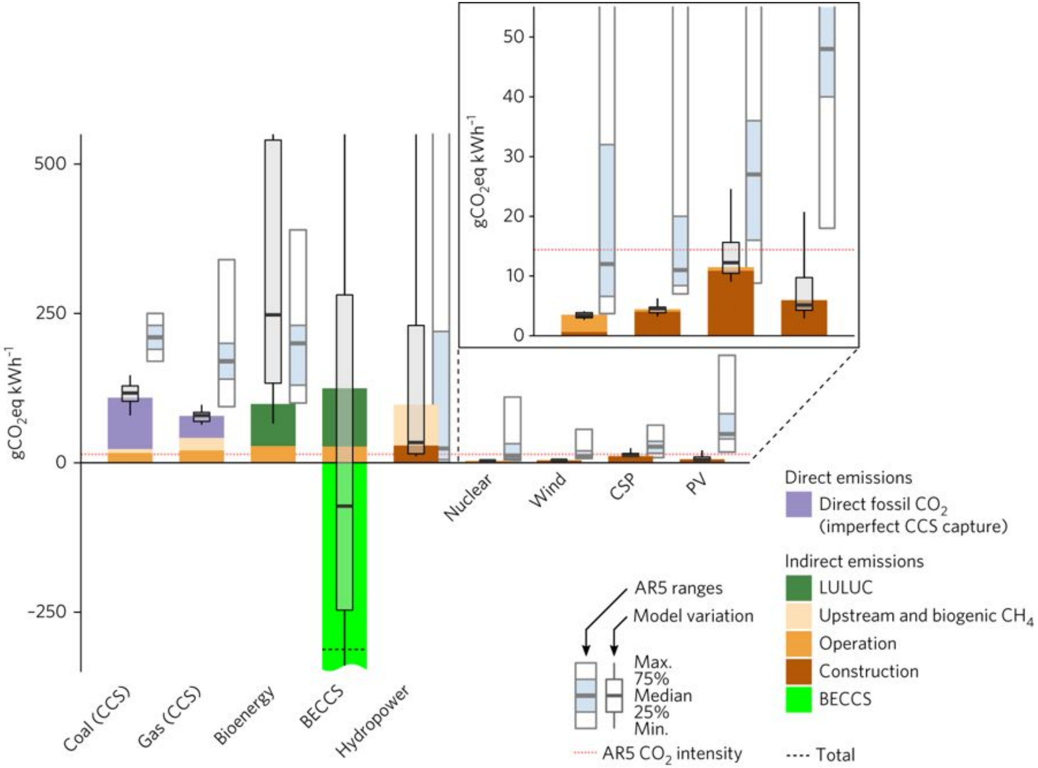
Life cycle greenhouse gas emissions in 2050 in REMIND



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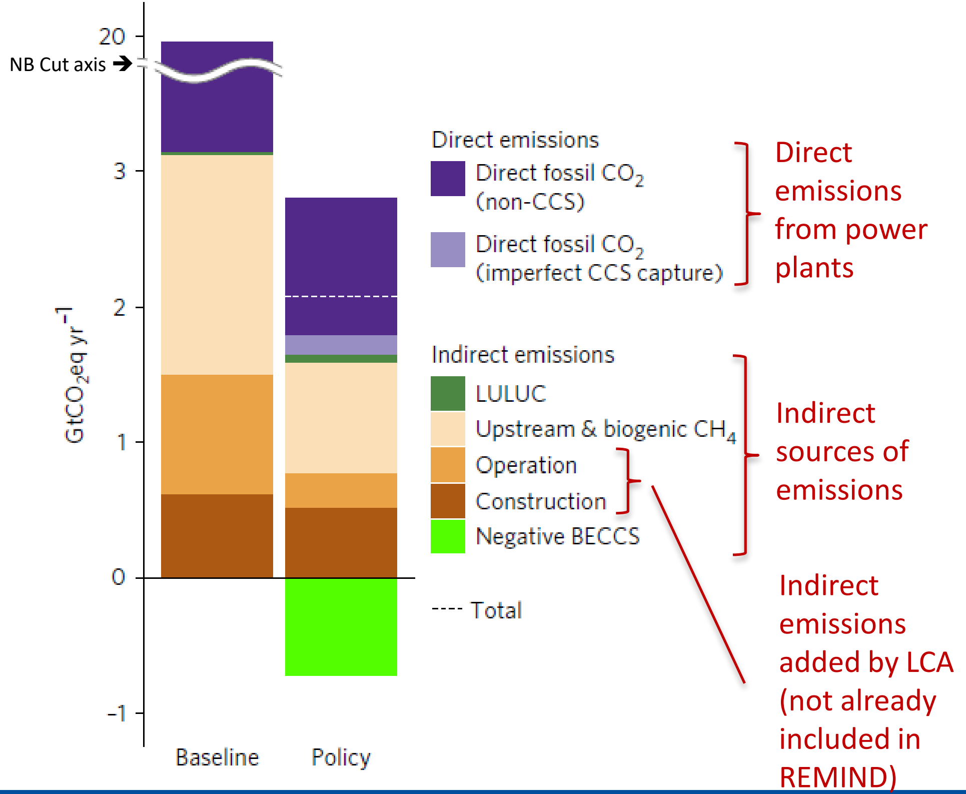
Total global 2050 life cycle emissions in REMIND



- Indirect emissions are small
  - Compared to 2050 Baseline direct emissions
  - And compared to current real-world direct emissions
- At the same time: Indirect emissions are important in relative terms in the climate policy scenario in 2050
- REMIND already accounts for the most important indirect sources of emissions
- Life cycle emissions can influence optimal technology choice, but not by much in this case:
  - In response to indirect emissions added by LCA, REMIND changes (only) 4% of technology selections

Source: Pehl et al. (2017)

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Final remarks

- Indirect emissions can influence optimal selections of technologies
  - We investigate this influence for the power sector, and find that it is fairly small
  - It is potentially more significant for other sectors, for example transport
- What LCA may contribute to energy scenario modelling:
  - Consistent treatment of indirect emissions of technologies
  - Identification of environmental win-win relationships or trade-offs looking at other impact categories than climate change (in other papers, under review)

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The research

- Arvesen, A., Luderer, G., M. Pehl, B.L. Bodirsky, E.G. Hertwich. 2018. Deriving life cycle assessment coefficients for application in integrated assessment modelling. *Environmental Modelling & Software* 99(1):111-125
- Pehl, M., Arvesen, A., Humpenöder, F., Popp, A., Hertwich, E.G., Luderer, G., 2017. Understanding future emissions from low-carbon power systems by integration of life cycle assessment and integrated energy modelling. *Nature Energy* 2: 939-945
- The LCA coefficients and an R script for using the coefficients in scenario analysis are available at: http://www.fp7-advance.eu/content/environmental-impacts-module

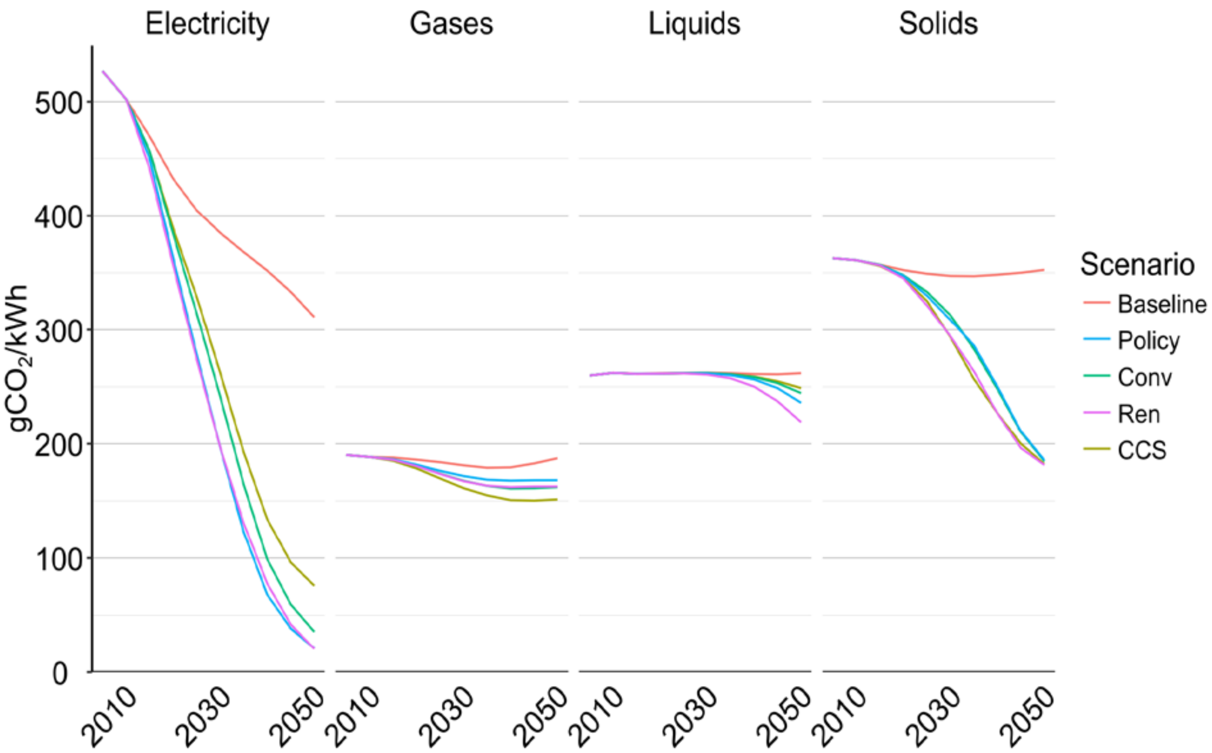
Me

- Email: anders.arvesen@ntnu.no
- Blog: https://www.ntnu.no/blogger/andersarvesen/
- Twitter: https://twitter.com/andersarvesen

Extra

Source: Arvesen et al. (2018)

CO2 intensities in REMIND



Source: Pehl et al. (2017) (supplementary)