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Fact sheet

Transition to a low-carbon energy infrastructure

Introduction

Despite the phase-out of fossil fuels in climate change mitigation pathways, building and operating a low-carbon infrastructure will produce emissions. In this work, we take a life-cycle approach to evaluate the environmental impacts of energy technologies and entire future energy systems.

Background and objectives

Energy pathways for climate stabilization imply fundamental changes in the composition and efficiency of energy supply. We know that future, low-carbon energy systems will be more based on electricity, will derive much more of its electricity from renewable sources, and will require expansions in electricity transmission and distribution networks.

In this work, we employ methods of life-cycle assessment (LCA) to study the environmental costs and benefits of selected energy technologies and entire future energy systems. The main focus is on electricity systems on a regional and multinational scale. The overall objective is to contribute to a better understanding of the environmental implications of potential transitions to a low-carbon energy infrastructure.

The research is expected to include the following elements:

1) Life-cycle assessments of scenarios for offshore grid and offshore wind power deployment in the North Sea.

2) Comparative assessment of the energy balance of electric power generation technologies; and scenario-based assessment of the energy balance of electricity production in aggregate.

3) Systematic exploration of how bottom-up and top-down LCA methods compare for electricity technologies, with a view to identifying improved or recommended practices for combining bottom-up and top-down approaches in hybrid frameworks.

Additionally, under the EU project ADVANCE, we are collaborating with teams from the energy scenario modelling community to incorporate life-cycle data into integrated assessment models.

Results

Life-cycle assessment of a North Sea power grid

The figure (see page 2) shows preliminary results of a life-cycle assessment of a North Sea power grid enabling enhanced interregional trade and integration of offshore wind power. The grid scenario explored is the Grand Design v05 scenario of the Windspeed project, and is the result of cost minimization analysis using a transmission expansion planning model. In the figure, results are shown for three impact categories and broken down to main components and environmental stressor sources.

According to the results, building and operating the grid cause emissions of 2.5 g CO2-Eq per kWh electricity transmission, or 36 million tonnes CO2-Eq in total. High-voltage transmission links ('ExpCab' in the figure) are the major cause of environmental damage.

About one third of the greenhouse gas emissions come from fossil-fuel burning in power stations, illustrating a

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general need to use fossil electricity of today to develop low-carbon energy infrastructure for tomorrow. Toxic effects in humans stem largely from disposed copper and iron mine tailings and overburden.

In the reference, we also present an extended life-cycle assessment considering not only North Sea power transmission, but also power generation in the North Sea and adjoining countries. Here we compare different energy scenarios, adopting North Sea grid configurations and electricity mixes in affected countries determined by the optimization procedure in Windspeed.

The results demonstrate that North Sea grid extension and the associated wind power development yield substantial environmental benefits by nine impact categories if displacing fossil fuels. Offshore grid and wind power entail an increased use of metals, however.

Usefulness and application

While it remains to be seen whether the influence of life-cycle effects in climate mitigation scenario analyses will be large or small, life-cycle considerations can potentially affect results with regard optimal timing and selection of mitigation measures, and feasibility of mitigation targets.

Enhancing our understanding of life-cycle effects may help to develop system designs and strategies that are effective in mitigating climate change, while also being sustainable in a broad sense.

In the North Sea grid assessment, we show that North Sea grid and wind power are environmentally beneficial by an array of criteria if displacing fossil fuels, but cause substantial metal use. ■

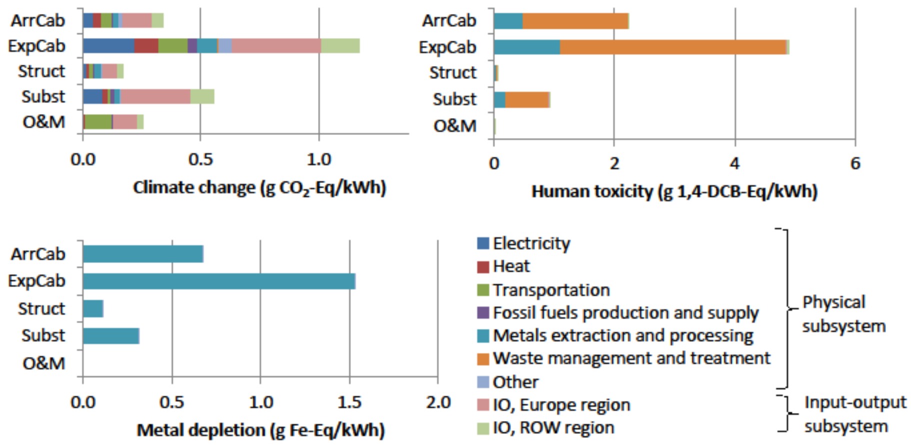

Figure. LCA results for a North Sea power grid by five components and nine stressor sources per kWh transmitted. Components: ArrCab = Array cables; ExpCab = Export cable; Struct = Substructure and topside for substation offshore; Subst = Electrical equipment (voltage source converter, transformer, breakers and switchgear) for substations offshore and onshore; O&M = Operations and maintenance. The reference provides results for seven additional impact categories.

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