# Fossil exploration and extraction and the returns to renewable energy

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## Extended abstract

To date, the global economy is heavily reliant on fossil resources. As fossil stocks continue to be burned at a rapid pace, investment efforts are required to satisfy the energy needs of the future.[1] These efforts can broadly take one of two forms: exploration and development of fossil reserves, or innovation and investment in renewable energy technologies. When successful, the former expands the readily recoverable reserves of the fossil resource, while the latter creates and deploys substitute technologies.

Next to the need for a stable energy supply, environmental concerns have put the composition of the global energy mix under increased scrutiny, and decarbonization has become an important policy goal. An adequate characterization of the steps required to advance towards a less carbon-intensive economy involves accounting for how past and continuing exploration of fossil reserves affects the scope for the development and deployment of renewable substitutes.

Over the past decades, the debate surrounding fossil reserves has notably shifted; for long run sustainability, the main concern is no longer the finiteness of fossil resources, but rather their contributions to the climate change problem. Put differently, rather than too little oil, we likely face a problem of 'too much oil in the ground'. In this context, the presence of large stocks of previously developed resource reserves is often cited as a barrier to the development and deployment of renewable energy technologies. One of the major arguments is that an expansion of the renewable capacity risks the potential stranding of assets, both in the fossil extraction industry as well as the industry that transforms fossil resources, such as oil refining and fossil energy plants. Simultaneously, a recent report

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[1] Oil for instance makes up for more than 1/3 of the primary energy consumed globally (BP, 2018).

by the IEA highlights that given current policies and current investment in developing accessible fossil reserves, there is a substantial risk of a fossil supply shortfall in the next decade (IEA, 2018). This insufficiency of near-term fossil is potentially conducive of a renewable capacity expansion.

In this vein, we study how the presence of previously developed fossil reserves, as well as the ongoing and potential development of new reserves, affect the scope for the expansion of the renewable energy capacity.

With this purpose, we put forward a dynamic resource management model with resource exploration and extraction.[2] In this framework, the economy's energy needs can be satisfied using either fossil or renewable resources. Fossil resources need to be explored and developed before they are available for extraction; this generates a need to continuously build reserves over time. Additionally, realistic limits on the rate at which resources can be extracted provide a rationale for keeping positive levels of developed reserves, which is consistent with empirical facts. We find that if developed reserves are insufficient to meet the economy's fossil energy needs, i) the rate of fossil extraction will be equal to its maximum, and ii) exploration will be maximal to quickly recover stock. Likewise, if developed fossil reserves are plentiful, the rate of extraction will be such that energy needs are met, and exploration will be postponed to future periods when reserves are lower.

We show that when such continued fossil exploration and development is accounted for, the societal return to expanding the capacity of a substitute source of renewable energy becomes intricately linked to the current state of the fossil reserves. If currently developed reserves are low relative to the energy requirements of the economy, the return to renewable expansion exceeds the marginal cost of fossil energy. Conversely, if currently developed reserves are more than sufficient to meet the energy requirements of the economy, the return to renewable expansion will fall short of the marginal cost of fossil energy and will be lower the greater the excess of fossil reserves.

An expansion of the renewable capacity allows the economy to save on costs associated to fossil energy, namely the cost of exploration and extraction (use) of fossil resources. In addition, it might allow the economy to satisfy any unmet energy needs. When current fossil energy capacity falls short of the immediate fossil energy needs, an expansion of the renewable capacity will be used to serve unmet energy demand rather than substitute away the available fossil capacity in the short run. On the contrary, when fossil reserves are plentiful, and hence the fossil capacity exceeds the immediate fossil energy needs, a

[2]Between 2013 and 2017 exploration and development expenditures of the 50 largest US oil and gas companies amounted to 495 billion USD, accounting for 75% of their total capital expenditure over this 5-year period (EY, 2018). Simultaneously, worldwide oil production—although slowly—has continued to grow, reaching an all time high of 92.6 million barrels per day in 2017 (BP, 2018).

renewable expansion immediately crowds-out the fossil supply. Jointly, this implies that we identify a negative relationship between currently developed fossil reserves and the societal returns to an expansion of renewable energy capacity.

Our results have several implications. First, they suggest a (weakly) positive relationship between resource prices and returns to renewable energy; returns to renewable energy are high if currently developed reserves are insufficient to satisfy fossil energy demand, in this situation also fossil energy prices will tend to be high. Second, when fossil reserves are currently low, there might be limited time window during which a renewable capacity expansion is worthwhile; when reserves are low, market forces will induce reserves to recover, reducing the scope for a renewable expansion. Third, the larger the renewable expansion, the lower the fossil energy needs relative to the level of developed reserves. From here, it follows that the marginal return to renewable expansions will decline in the size of the expansion. In the limiting case where the renewable expansion fully phases out fossil energy, the marginal return to the expansion is equal to only the use cost of fossil; for oil, this amounts to only about half of its total per-barrel cost. If one considers that renewable energy expansions are typically "non-marginal", the size of the expansion is then relevant to evaluate whether such expansion is worthwhile. For many countries, the addition of a single nuclear plant implies an increase in electricity supply of multiple percentage points. At the global level, the IEA (2018) projects more than a doubling of renewable energy use over the next 20-30 years, as well as rapid increase in the electric vehicle penetration rate.[3] This result prevails independent of assumptions about resource substitutability, the cost of fossil expansions, or potential environmental externalities associated with the fossil resource. Rather, it results from the indirect effect such expansions have on optimal resource exploration and extraction decisions.

Fourth, as expected, the more prominent a potential environmental externality associated to the use of fossil, the higher the return to a renewable capacity expansion. However, internalizing a previously unaccounted for environmental externality, will increase the return to the renewable expansion relatively more when currently developed fossil reserves are plentiful and the renewable expansion crowds out fossil supply. Finally, our results highlight the importance of explicitly separating decisions and costs associated to the development of fossil reserves and extraction and use of fossil resources in the consideration of renewable energy expansions. Attributing all costs associated to fossil energy to the extraction decision, as is the (implicit) approach in the literature to date, likely leads to an overestimation of the scope of a renewable energy expansion, in particular if the proposed expansion is large.

[3]Though electricity is not necessarily generated by renewable sources, this will imply a substantial reduction in demand for gasoline and diesel fuel, and thus oil.

## References


- British Petroleum (2018). *BP statistical review of world energy*, 67th edition. London: British Petroleum.
- EY (2018). *US oil and gas reserves and production study.*
- International Energy Agency. (2018). World Energy Outlook 2018, Executive Summary.