Sanaa increased renewable energy penetration

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The analysis is based on the scenarios aiming to reach a net-zero CO2 power system. In terms of modelling methodology, the scenarios are divided into two groups: (i) optimisation of the Best Policy Scenario (BPS) and alternative faster ET scenarios based on BPS, and (ii) replication of reputational scenarios generated by the International Energy Agency (IEA), and Teske and the German Aerospace Centre (DLR).

All scenarios (described in Table 1) are run from 2015 to 2050 with 5-year time intervals for the nine major regions. The global-level power sector model presents an aggregated version of all nine major regions.

The LUT-EROI not only improves on the previous key shortcomings of EROI estimation but also achieves sound comparability with different system types. This study relies on nine global ET scenarios reported in Aghahosseini et al.6. The nine transition scenarios are modelled by dividing the world into nine major regions. These scenarios are five LUT-BPS, two scenarios published by the IEA, and two scenarios published by Teske/DLR. Even though the choice of these scenarios were primarily motivated by the availability of the required detailed data for the EROI calculation, they also provide a representation of the variety of discussed transition paths.

The detail study of the corresponding systemwide EROI is presented below and further information on each scenario is provided in Methods. The systemwide EROI was estimated at the point of electricity generation and consumption, with estimates at the point of final energy consumption leading to lower EROI. Due to similarities in trends in this result, we present the detail using point of final consumption (F) and provide the point of generation (G) estimation, not including losses from electricity transmission and distribution, in Supplementary Information Note 4.

Figure 2 illustrates the global EROI results for nine main scenarios. During the 30-year ET period, global EROI values were shown to remain above 16, maintaining a value above 10, the upper limit for the net energy cliff22,38. The fluctuations in the EROI trends at specific periods are largely driven by dramatic changes in system composition and the prioritisation order of technology types, in other words, differences in ET pathways.

a BPS scenarios, b IEA and Teske/DLR scenarios during the energy transition (ET) period. Changes in variable renewable energy (VRE) penetration and EROI versus (vs) VRE penetration are shown in c and d.

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VRE penetration values only include solar photovoltaic and wind power technologies. (F) represents the final consumption.

From 2015 to 2020, Fig. 2 provides a summary of the historical situation of global power systems. The EROIs for all scenarios start from 18.8 and increase to above 20. The growing trends are observed because of the slow integration of renewables into modern power systems, which reduce fossil fuels use and thus improve EROI, while further enabling technologies are not yet required.

EROI trends relationships with a storage energy capacity, b curtailment, c the ratio of CO2 to generated electricity and d levelised cost of electricity (LCOE) versus (vs) year. Note that the represented variable renewable energy penetration values only include solar photovoltaic and wind power technologies. (F) represents the final consumption. BPS scenarios are shown in blue and grey lines and dots, IEA scenarios in yellow and Teske/DLR scenarios in green lines and dots.

On the other hand, low EROI was found to be one of the cleanest options (Fig. 3c, d), while systems with high EROI are usually the ones with high CO2 emissions as observed from IEA scenarios, which are not achieving net-zero CO2 power systems by 2050. Thus, a multicriteria system designing will provide a better means of defining the proper path. The presence of high uncertainty due to data aggregation39, other limitations and sensitivity covered in Solomon et al.27 are the additional reasons justifying the need of multicriteria future system designing.

Note that the five BPS scenarios created with a slightly higher demand projection that reaches 48.38 PWh in 2050 as compared to the IEA and Teske/DLR scenarios, which remain in the range of 45-46.5 PWh. However, no clear evidence was found that demand influenced the EROI trends such as BPS-WF scenarios show a slower decline compared to Teske/DLR scenarios. Further in-depth examination of the data also reveals that the system composition and the technology choice have more impact on the trend.

a BPS scenarios, b BPS-plus scenarios, c IEA scenarios, and d Teske/DLR scenarios. The cut-off point for (F) EROI is the net electricity delivered to end-users (including transmission and distribution losses). (AEF) denotes the annual energy investment flow (dash lines), while (SF) (for Sgouridis et al.43 final net electricity delivering to end-users) represents the systemwide energy investment flow (solid lines).