GLOBAL ENERGY SYSTEM BASED ON 100% RENEWABLE ENERGY - POWER SECTOR

COMMISSIONED BY

ENERGY WATCH GROUP

Manish Ram, Dmitrii Bogdanov, Arman Aghahasseini, Solomon Oyewo, Ashish Gulagi, Michael Child and Christian Breyer

Lappeenranta University of Technology
9th NCE Researchers' Seminar,
Lappeenranta, December 11-13, 2017
Agenda

- Background
- Overview of the Study
- Findings
- Impact
Background

- Energy Watch Group commissioned LUT Solar Economy Group to conduct a research study on Global Energy System based on 100% Renewable Energy with a focus on the Power Sector initially (in 2017) and then integrating other sectors of Mobility, Heating and Industry into the study (in 2018).

- Objective of the study was to describe a transition pathway for the global energy system from its current status towards a fully sustainable energy system by the year 2050 in accordance with the Paris Agreement. Assessing the resource availability, future demand for energy, the optimal mix considering costs and the socio economic benefits of a fully sustainable energy system.

- The main message of the report is ‘A global transition to 100% renewable electricity is feasible at every hour throughout the year and more cost effective than the existing system, which is largely based on fossil fuels and nuclear energy. The energy transition is no longer a question of technical feasibility or economic viability, but of political will’.

Background: very comprehensive supplementary

We have intended from the very beginning to deliver detailed energy transition insight on global-local level, therefore we have created 1500 (!) slides, structured in 1 global, 9 major region and 92 country slide sets, all uploaded to ResearchGate and cross-linked.
Agenda

- Background
- Overview of the Study
- Findings
- Impact
Chp.1: Overview of the global energy landscape

Key insights:
- Global renewable power capacity including hydro has doubled since 2007, from around 1000 GW to about 2017 GW by the end of 2016.
- The addition of renewable power capacity in the year 2016, nearly 140 GW, was equivalent to 55% of all generating capacity added globally.
Chp.2: Transitioning to a fully renewable powered energy system: Methodology and influencing factors

- The world is structured into 9 major regions, which are further divided to 145 sub-regions.
- Some sub-regions are comprised of more than one smaller (by population) country, while others represent parts of a larger country.
- The sub-regions are interconnected by power lines within the same country.
- All results shown in this presentation are for the Power Scenario.
The technologies applied for the energy system optimisation include those for electricity generation, energy storage and electricity transmission.

The model is applied at full hourly resolution for an entire year.

Real weather data were used for assessing the solar, wind and hydro resources.

The LUT model as of 2017 is the only one to run at full hourly resolution on a global-local scale.

The LUT model will be further applied to all energy sectors for a follow-up study.
Chp.2: Resource potential for PV and Wind

Key insights for solar PV:
- It is the most evenly distributed energy resource around the world.
- It has diurnal variation.
- Seasonal stability in the Sun Belt region is more in comparison to other regions.
- Stronger seasonality in the northern hemisphere is observed.

Key insights for wind energy:
- It has uneven global distribution.
- Excellent conditions are available in all major regions of the world.
- It has stronger seasonal variation in availability of the resource.
Chp.2: Development of electricity demand

Key insights:
- A global cumulative average annual growth rate of about 2.0% in the energy transition period is assumed, comparable to 1.9% assumed by IEA.
- The world population is expected to grow from 7.3 to 9.7 billion people, while the global average per capita electricity demand rises from 3.2 to 5.0 MWh.
- The global electricity demand is assumed to increase from 24,310 TWh in 2015 to around 48,800 TWh in the year 2050.
Chp.2: Methodology for estimating job prospects of the global energy transition

<table>
<thead>
<tr>
<th>Employment Type</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Jobs</td>
<td>( \text{Installed Capacity per year (MW/year)} \times \text{Manufacturing EF (job-years/MW)} \times \text{Decline Factors based on Capex} \times \text{Global employment multiplier} )</td>
</tr>
<tr>
<td>Construction and Installation Jobs</td>
<td>( \text{Installed Capacity per year (MW/year)} \times \text{Construction and Installation EF (job-years/MW)} \times \text{Decline Factor based on Capex} \times \text{Global employment multiplier} )</td>
</tr>
<tr>
<td>Operation and Maintenance Jobs</td>
<td>( \text{Cumulative Capacity (MW)} \times \text{Operation and Maintenance EF (jobs/MW)} \times \text{Decline Factor based on Opex} \times \text{Global employment multiplier} )</td>
</tr>
<tr>
<td>Fuel Jobs</td>
<td>( \text{Primary energy demand (PJ)} \times \text{Fuel EF (Jobs/PJ)} \times \text{Global employment multiplier} )</td>
</tr>
<tr>
<td>Transmission Jobs</td>
<td>( \text{Investments per year (bₜ)} \times \text{Transmission EF (jobs/bₜ)} \times \text{Global employment multiplier} )</td>
</tr>
<tr>
<td>Total Jobs</td>
<td>( \text{Manufacturing Jobs} + \text{Construction and Installation Jobs} + \text{Operation and Maintenance Jobs} + \text{Fuel Jobs} + \text{Transmission Jobs} )</td>
</tr>
</tbody>
</table>

Key factors:
- Direct employment includes jobs in manufacturing, construction and installation, operations and maintenance, fuel supply and transmission associated with electricity generation.
- EF is the Employment Factor, which is the number of jobs per unit of capacity, separated into manufacturing, construction and installation, operation and maintenance, and per unit of primary energy of fuel supply.
Chp.3: Energy Transition in Capacity and Generation

**Installed Capacity**

<table>
<thead>
<tr>
<th>Year</th>
<th>Installed Capacity (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>0.5</td>
</tr>
<tr>
<td>2030</td>
<td>2.0</td>
</tr>
<tr>
<td>2040</td>
<td>2.5</td>
</tr>
<tr>
<td>2050</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Electricity Generation**

<table>
<thead>
<tr>
<th>Year</th>
<th>Primary Electricity Generation (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>1.0</td>
</tr>
<tr>
<td>2030</td>
<td>3.0</td>
</tr>
<tr>
<td>2040</td>
<td>4.0</td>
</tr>
<tr>
<td>2050</td>
<td>5.0</td>
</tr>
</tbody>
</table>

**Key insights:**

- Wind energy increases to 32% by 2030 and beyond 2030 solar PV becomes more competitive.
- Solar PV increasingly drives most of the system, while wind energy continues to play a vital role with around 18% of the share in 2050.
- Solar PV supply share increases from 37% in 2030 to about 69% in 2050 becoming the least cost energy source.
Chp.3: Storage Requirements

Key insights:
- Batteries are the most important supporting technology for solar PV
- Storage output covers 31% of the total demand in 2050, of which 95% is contributed by batteries alone
- A significant share of gas storage is installed to provide seasonal storage
Chp. 4: Electricity System Cost and Investments during the Energy Transition

Key insights:

- The global power system LCOE remains stable for the first periods, showing a gradual decline from 70 €/MWh to 59 €/MWh from 2015 to 2040, including all generation, storage, curtailment and parts of the grid costs.

- Beyond 2040 the LCOE further declines to 52 €/MWh by 2050, signifying that larger capacities of RE addition result in reduction of energy costs.

- After an initial increase, the investment requirements decline after 2030 to stabilise between 2040 to 2050.
Chp.5: CO2 Emissions Reduction

Key insights:
- GHG emissions can be reduced from about 11 GtCO$_{2eq}$ in 2015 to zero by 2050, while the total LCOE of the power system declines and more than 500 b€ worth of CO$_{2eq}$ is saved between 2020 to 2030.
- The presented 100% RE scenario for the global power sector supports the accomplishment of goals set by the Paris Agreement.
- What is even more important is the observation that a deep decarbonisation of 95% to 0.57 GtCO$_{2eq}$ by 2035 and 98% to 0.24 GtCO$_{2eq}$ by 2040 is possible, which is well before 2050, while gradually lowering the energy system LCOE.
Chp.5: RE Job Prospects

Key insights:
- A global 100% RE based electricity system has the potential to create 36 million jobs in 2050, compared to 19 million jobs in the 2015 electricity system
- Fossil and nuclear energy-related jobs can be easily substituted by RE-related ones
- Solar PV and battery storage will be prime job creators 2030 onwards
- More stable jobs will be available in operation and maintenance
- The total jobs per generated electricity will first increase due to strong investment needs and will stabilise towards 2050 comparable to the current level
Chp.6: Policy perspectives for the low-cost power system of the future

To ensure a smooth, fast and cost-effective transition to 100% renewable energy, governments need to adopt national legislative acts, which ensure the sufficient flow of private investment in renewable energy and storage technologies. Although public financing is indispensable, private investment is instrumental in enabling competition and a rapid scaling-up of the renewable energy sector. The following political measures and instruments are key:

- Instruments, enabling direct private investments in renewable energy and other zero-emission technologies.
- Phasing-out all state subsidies to fossil fuel and nuclear energy generation
- Tax exemptions for investments in renewable energy
- Introducing carbon and radioactivity tax
- Promoting research and education in the sphere of renewable energy and zero-emission technologies
Agenda

- Background
- Overview of the study
- Findings
- Impact
100% renewable electricity generation is technically feasible

- In 2050, solar PV accounts for 69%, wind energy 18%, hydropower 8% and bioenergy 2% of the total electricity mix globally.
- Gas generation is only from renewable energy based gas (bio-methane and power-to-gas)
- Nuclear power still accounts for negligible 0.3% of the total electricity generation, due to the end of its assumed technical life, but could be phased out earlier.
100% renewable electricity generation is more cost effective

- Total levelised cost of electricity (LCOE) on a global average for 100% renewable electricity in 2050 is 52 €/MWh compared to 70 €/MWh in 2015.
- These costs include generation, curtailment, storage and some grid costs.
- Stable and secure electricity supply for all hours of a year is observed.
The global energy transition to a 100% renewable electricity system creates 36 million jobs by 2050 in comparison to 19 million jobs by 2015.

Governments should start programmes to convert coal jobs to jobs for renewable energy.
The total losses in a 100% renewable electricity system are around 26% of the total electricity demand, compared to the current system in which about 58% of primary energy input is lost.

Thermal power plants (coal, gas, oil, nuclear, biomass) lose much of the primary energy input.

Curtailment is a low-cost flexibility option in future.
Global greenhouse gas emissions significantly reduce from about 11 GtCO$_{2eq}$ in 2015 to zero emissions by 2050 or earlier, as the total LCOE of the power system declines.
Agenda

- Background
- Overview of the study
- Findings
- Impact
Impact

There was extensive media coverage of the report around the globe! LUT mentioned in all the stories...

Some of the leading energy media covered the report: PV magazine, Clean Technica, Renewables Now, Innovators magazine and many others.

Also, the reporting was in various languages and a Czech translation of the report is on the way [http://www.eurosolar.cz/nova-studie:-100-obnovitelna-elektrina-po-celem-svete-je-proveditelna-a-nakladove-efektivnejsi-nez-stavajici-system-1404042527.html](http://www.eurosolar.cz/nova-studie:-100-obnovitelna-elektrina-po-celem-svete-je-proveditelna-a-nakladove-efektivnejsi-nez-stavajici-system-1404042527.html)

Some of the links,

- [http://www.editiontruth.com/study-proves-100-renewable-power-feasible/](http://www.editiontruth.com/study-proves-100-renewable-power-feasible/)
- [https://www.pv-magazine.de/2017/12/05/solarenergie-die-unverzichtbare-tragende-saeule-der-energiewende/](https://www.pv-magazine.de/2017/12/05/solarenergie-die-unverzichtbare-tragende-saeule-der-energiewende/)
- [https://www.energynews.es/un-estudio-confirma-que-un-sistema-100-renovable-de-electricidad-es-factible-y-rentable/](https://www.energynews.es/un-estudio-confirma-que-un-sistema-100-renovable-de-electricidad-es-factible-y-rentable/)

After its release it was shared widely on social media platforms. The report had quite a lot of reads on [ResearchGate](https://www.researchgate.net) and still continuing to make an impact.
Impact

The leading Spanish energy media made a video for their channel!
THANKS FOR YOUR ATTENTION
FURTHER INFORMATION

The report along with all the references and supplementary data associated can be found in the following links:

Link to the study:  

Link to the slide set which leads to regional information and their corresponding countries and sub-regions:  
https://www.researchgate.net/publication/320739515_Global_100_RE_System_Global_Overview