Heading towards a New Climate Economy
Shifting the Trillions for a Just Transition

F20 High-Level Forum in Tokyo, 13 June 2019

Dr. Sven Teske
2018, September 11th – the Climate 9/11
Today, September 11th 2050:
The world successfully decarbonized it’s energy system and implement a sustainable circular economy. Politicians, financial institutions and industry now understand that to fight climate change is not a green issue. It’s a matter of survival.
How responsible world leaders decided in the year 2019 to implement the Paris Climate Agreement: The Plan
Global Trends in the Energy Sector

- New Power Generation Capacity mainly solar PV and Wind as most economic
- High shares of variable power generation = the end of base load power plants
- Digitalisation of electricity:
  - Decentralised generation and Storage
  - Consumer turn into Prosumer
- Sector-Coupling:
  - Increased electrification in transport and heating sector

The One Earth Climate Model takes those trends into account.
Project Scope

- Development of a 100% renewable energy scenario
- De-carbonization of the entire global energy sector within one generation (until 2050).
- Based only on technologies currently available or under development, excluding BECCS and nuclear energy.
- 10 World region scenario (based on IEA WEO)
- All sectors: power, buildings, industry and transport
- Power Sector Analysis: Modelled in hourly resolution to assess
  - storage demand
  - Increased interconnection between regions requirements for the integration of high shares of variable renewable energy, such as solar and wind for all regions.
- Non-energy related green-house-gas (GHG) emission scenarios - to define a sustainable pathway for land-use change.

All pathways are evaluated in regard to their implicit use of the carbon budget and their exceedance probabilities for 1.5°C and 2°C
Methodology: Interaction of Models

**Modelling cluster**

- **Transport model (TRAEM)**
  - freight & passenger transport demand by mode
  - energy demand by transport mode
  - annual power demand & supply
  - RE generation curves

- **Resource model ([R]E SPACE)**
  - GIS based renewable energy potentials based on weather & land use data

- **Energy system model (EM)**
  - bottom-up simulation of future energy balances based on GDP, population, technology, & energy intensity development in all sectors and for 10 world regions

- **Power system model ([R]E 24/7)**
  - hourly balancing of electricity supply & demand in spatial resolution for sub regional clusters

- **Reduced complexity carbon cycle and climate model (MAGICC)**
  - to calculate the climatic effects of multi-gas pathways

- **Simplified land based sequestration model**
  - complementing reforestation, restoration, sustainable use and agroforestry options.

- **Generalized Equal Quantile Walk**
  - complementing non CO2 gases based on the IPCC scenarios database characteristics

**Output**

- total climate change effects
- full energy balances: final energy demand power, heat & transport, supply structure, primary energy demand by fuel, emission, investment
- balanced RE power system, storage demand, curtailment
Methodology: Regional Renewable Energy Potential

Renewable Resource Assessment [R]E-SPACE:

RE-SPACE is based on a Geographic Information Systems (GIS) approach and provides maps of the solar and wind potentials in space-constrained environments. GIS attempts to emulate processes in the real world, at a single point in time or over an extended period (Goodchild 2005). The primary purpose of GIS mapping is to ascertain the renewable energy resources (primarily solar and wind) available in each region. It also provides an overview of the existing electricity infrastructures for fossil fuel and renewable sources.

To assess the renewable energy potential based on the area available, all scenario-relevant regions and sub-regions were analysed with the [R]E-SPACE methodology, to quantify the available land area in square kilometres with a defined set of constraints:

- Residential and urban settlements;
- Infrastructure for transport (e.g. rail, roads);
- Industrial areas;
- Intensive agricultural production land;
- Nature conservation areas and national parks;
- Wetlands and swamps;
- Closed grasslands (as the land-use type).
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Assumptions—Transport Model

The 5.0°C Scenario (reference scenario):

  - IEA’s projections only extend to 2040, we extrapolate their key macroeconomic and energy indicators forward to 2050.
  - existing international energy and environmental policies
  - continuing progress in electricity and gas market reforms, the liberalization of cross-border energy trade, and recent policies designed to combat environmental pollution.
  - No additional policies to reduce GHG emissions.

The 2.0°C Scenario:

- global energy-related CO₂ emission budget of around 590 Gt between 2015 and 2050.
- Energy efficiency and renewable energy driven
- Assumes continued rapid expansion of RE industry and electrification across all sectors

The 1.5°C Scenario:

- global energy-related CO2 emission budget of around 450 Gt, accumulated between 2015 and 2050
- requires immediate action to realize all available options.
- Technical benchmark scenario
Assumptions – Transport Model

- **Aviation**
- **Cars**
- **Passenger Train**

Graphs showing the transport evolution from 2015 to 2050 under 5.0°C, 2.0°C, and 1.5°C climate targets. The graphs compare different modes of transport: Passenger Train, Aviation (Domestic), Passenger Car, Bus, 2- & 3-Wheeler, Freight Train, and Truck.
Key Results
## Key Results

### Global Renewable Energy Potential

<table>
<thead>
<tr>
<th>Region</th>
<th>Subregion</th>
<th>Solar Potential Availability for Utility-Scale Installations</th>
<th>Space Potential</th>
<th>Onshore Wind Potential Availability for Utility-Scale Installations</th>
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Energy Intensity:

Compared with the 5.0°C case based on the Current Policies Scenario of the IEA, the alternative scenarios follow more stringent efficiency levels.

The 1.5°C Scenario represents an even faster implementation of efficiency measures than the 2.0°C Scenario. The 1.5°C Scenario involves the decelerated growth of energy services in all regions, to avoid any further strong increase in fossil fuel use after 2020.

The global average intensity drops from 2.4 MJ/$GDP in 2015 to 1.25 MJ/$GDP in 2050 in the 5.0°C case compared with 0.65 MJ/$GDP in the 2.0°C Scenario and 0.59 MJ/$GDP in the 1.5°C Scenario.

The average final energy consumption decreases from 46.3 GJ/capita in 2015 to 28.4 GJ/capita in 2050 in the 2.0°C Scenario and to below 26 GJ/capita in the 1.5°C Scenario. In the 5.0°C case, it increases to 55 GJ/capita.
Global: final energy demand by sector:

Combining the assumptions for population growth, GDP growth, and energy intensity produced the future development pathways for the global final energy demand develops as follows:

- **5.0°C Scenario**, the total final energy demand will increase by 57% from 342 EJ/yr in 2015 to 537 EJ/yr in 2050.
- **2.0°C Scenario**, the final energy demand will decrease by 19% compared with the current consumption and reach 278 EJ/yr by 2050.
- **1.5°C Scenario** will reach 253 EJ, 26% below the 2015 demand. In the 1.5°C Scenario, the final energy demand in 2050 is 9% lower than in the 2.0°C Scenario.
Global electricity demand by sector:

Electrification will lead to a significant increase in the electricity demand by 2050.

- **2.0°C Scenario**: Electricity demand for heating will be about 12,600 TWh/yr due to electric heaters and heat pumps, and in the transport sector there will be an increase of about 23,400 TWh/yr due to increased electric mobility.

- The generation of hydrogen (for transport and high-temperature process heat) and the manufacture of synthetic fuels (mainly for transport) will add an additional power demand of 18,800 TWh/yr.

- The gross power demand rises from 24,300 TWh/yr in 2015 to 65,900 TWh/yr in 2050 in the 2.0°C Scenario, 34% higher than in the 5.0°C case.

- **1.5°C Scenario**, the gross electricity demand will increase to a maximum of 65,300 TWh/yr in 2050.
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Global: Electricity Generation and Capacity:

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<th>2.0°C C</th>
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<th>2.0°C C</th>
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<th>2.0°C C</th>
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Key Results – Global and Regional Long-term Energy Pathways
### Global: Electricity Generation – Investment Costs versus Fuel Cost Savings:

#### ACCUMULATED INVESTMENT COSTS

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<th>2015-2020</th>
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<th>2031-2040</th>
<th>2041-2050</th>
<th>2015-2050 average per year</th>
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<td>difference 5.0C minus 1.5C</td>
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<td>conventional (fossil + nuclear) billion $</td>
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#### ACCUMULATED FUEL COST SAVINGS

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<td>savings cumulative 1.5C versus 5.0C</td>
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Global: Energy Supply – Transport:

- 5.0°C Scenario: 50% increase of transport energy demand by 2050.

- 2.0°C Scenario, assumed technical, structural, and behavioural changes will reduce the energy demand by 66% (96 000 PJ/yr) by 2050 compared with the 5.0°C Scenario. A

- 1.5°C Scenario: Additional modal shifts, technology switches, and a reduction in the transport demand reduce energy demand further - 74% (or 108 000 PJ/yr) in 2050 compared with the 5.0°C case.

- 2.0°C Scenario: Electricity share 12% by 2030 and 47% in 2050. In 2050 8 430 PJ/yr of hydrogen will be used in the transport sector, as a complementary renewable option.

- Biofuel use is limited in 2.0°C and 1.5°C Scenarios to a maximum of around 12 000 PJ/yr / 10 000 PJ/yr.
Global: Primary Energy Supply:

- 5.0°C: 837 EJ in 2050
- 2.0°C Scenario: 439 EJ/yr in 2050 (-21%)
  - -48% compared to 5.0°C Scenario
- 1.5°C Scenario: 412 EJ in 2050
- Both the 2.0°C and 1.5°C Scenarios aim to rapidly phase-out coal and oil.
- Renewable energy share:
  - 2.0°C Scenario: 35% (2030); 92% (2050) (= non-energy use)
  - 1.5°C Scenario: 40% (2030) 100% (2050)
- Nuclear energy will be phased-out in both the 2.0°C and 1.5°C Scenarios Around 2040.
Global: Bunker Fuel Supply:

• Bunker fuels: Fuel supply for international aviation and
  
  • Their use and related emissions are not usually directly allocated to the regional energy balances.

• 2015: Annual bunker fuels consumption 16 000 PJ/a,
  
  • Aviation: 7 400 PJ/a + Shipping: 8 600 PJ/a

• 2009 – 2015: Increase of bunker fuel consumption by 13%.

• 2015 CO₂ emissions from bunker fuels: 1.3 Gt
  
  • approx. 4% of global energy-related CO₂ emissions.

• Bunker fuels are replaced by biofuels or synthetic liquid fuels (RE produced); Hydrogen not used.

• Renewable synthetic fuel production for bunker fuels:
  
  • Africa, the Middle East, and Australia
Global: Energy-related CO₂:

5.0°C Scenario:
- 43.5 Gt CO₂/year in 2050 (+40%)

2.0°C Scenario:
- 7.07 Gt CO₂/year in 2040, zero in 2050
- 587 Gt CO₂ (2015–2050)

1.5°C Scenario:
- 2.65 Gt CO₂/year in 2040 t, zero in 2050
- 450 Gt CO₂ (2015-2050).
Global: Power Generation Structure

- Variable Renewables increase from around 5% to 65%
- Dispatchable Fossil decrease from around 60% to 7%
- The role of variable and fossil fuel based generation will swap
- There will be no power plants dedicated to supply for base-load after

Key Results – Global and Regional Power Sector Analysis

### Achieving the Paris Climate Agreement

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Global: Power Generation Structure

- **Limited dispatchable fossil and nuclear power plants:**
  - Coal, Lignite, and Nuclear power plants with limited ability to respond to changes in demand.
  - Power systems dominated by renewable energy usually contain high proportions of variable generation require quick reaction times (to ramp up and down). Limited dispatchable power plants cannot deliver these services and are therefore being phased-out.

- **Limited dispatchable renewable systems:**
  - CSP plants with integrated storage and co-generation systems with renewable fuels (including geothermal heat).
  - No second or minute reserve possible (yet), but can still be used as dispatch power plants for ‘day ahead’ planning.

- **Dispatchable fossil fuel power plants**
  - Gas power plants that have very quick reaction times and therefore provide valid power system services.

- **Dispatchable renewable power plants**
  - Hydropower plants (although they are dependent on the climatic conditions in the region where the plant is used),
  - Biogas power plants, and former gas power plants converted to hydrogen and/or synthetic fuel.
  - This technology group is responsible for most of the required load-balancing services and is vital for the stability of the power system, as storage systems, interconnections, and, if possible, demand-side management.

- **Variable renewables:**
  - Solar PV plants, onshore and offshore wind farms, and ocean energy generators. Ocean energy plants—tidal energy plants—is very predictable.
Global: Load Development by Region - 2.0°C and 1.5°C Scenario

Africa:
• + 534% by 2050
  • Favourable economic development
  • Increased access to energy services by households.

OECD Pacific:
• - 87% by 2030
  • Efficiency measures across all sectors
• 116% increase by 2050
  • Electric mobility
  • Increased Electrification of the process heat supply especially in the industry sector.
Key Results – Global and Regional Power Sector Analysis

Global: Estimated Investment in Battery and Pumped Hydro Storage

- Pumped Hydro market stable around $4 billion annually from 2021 till 2050
- Batteries sharp increase from $4.5 billion to $15 billion in 2030 and $65 billion in 2050

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<th>Estimated Storage investment costs</th>
<th>2015-2020</th>
<th>Average annual</th>
<th>2021-2030</th>
<th>Average annual</th>
<th>2031-2040</th>
<th>Average annual</th>
<th>2041-2050</th>
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<td>In $ billion</td>
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<td>44.5</td>
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<tr>
<td>Total</td>
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Summary: Required fossil fuel resources under the 2.0°C and 1.5°C trajectories

- 2.0°C Scenario: Global fossil fuel extraction industry must reduce production at a rate of 2% per annum
- 1.5°C Scenario: Minus 3% per annum
- International measures required to organize the economic and social transitions in the producing countries,
- Communities and workers need to be involved.

- The idea of a ‘just transition’ is well documented in the international literature. According to the International Labour Organization (ILO 2015), the concept was first mentioned in the 1990s, when North American unions began developing the concept of just transition.

The Paris Climate Agreement 2015, during the 21st session of the Conference of the Parties (COP 21) “decided to continue and improve the forum on the impact of the implementation of response measures (hereinafter referred to as the improved forum), and adopted the work programme, comprising two areas: (1) economic diversification and transformation; and (2) just transition of the workforce, and the creation of decent work and quality jobs”

(UNFCCC-JT 2016).
OE Climate Model: LDF 1.5C Scenario

- 50% chance of 1.5°C
- 67% chance of 1.5°C

- 2020: Peak fossil fuel & cement emissions
- +10 (cement)
- +65 GtCO2 Earth system feedbacks

- 392 net (2018-2037)
- 157 net (2018-2100)

Cumulative GtCO2

Annual GtCO2

Land sinks

Oceans sinks

2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

-20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50
Achieving the Paris Climate Agreement Goals

Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5°C and +2°C

Editors: Teske, Sven (Ed.)

Previews robustly modeled scenarios to achieve 100% renewable energy by 2050
Thank you

Dr Sven Teske

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