Accelerating the Energy Transition
Paths to Zero Carbon Energy

Technology trends, markets, policies

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Why do we need an energy transition ?

Drivers vary by country

- Climate change mitigation
- Local air pollution
- Energy import dependency/energy security
- Lower cost energy
- Economic activity and jobs

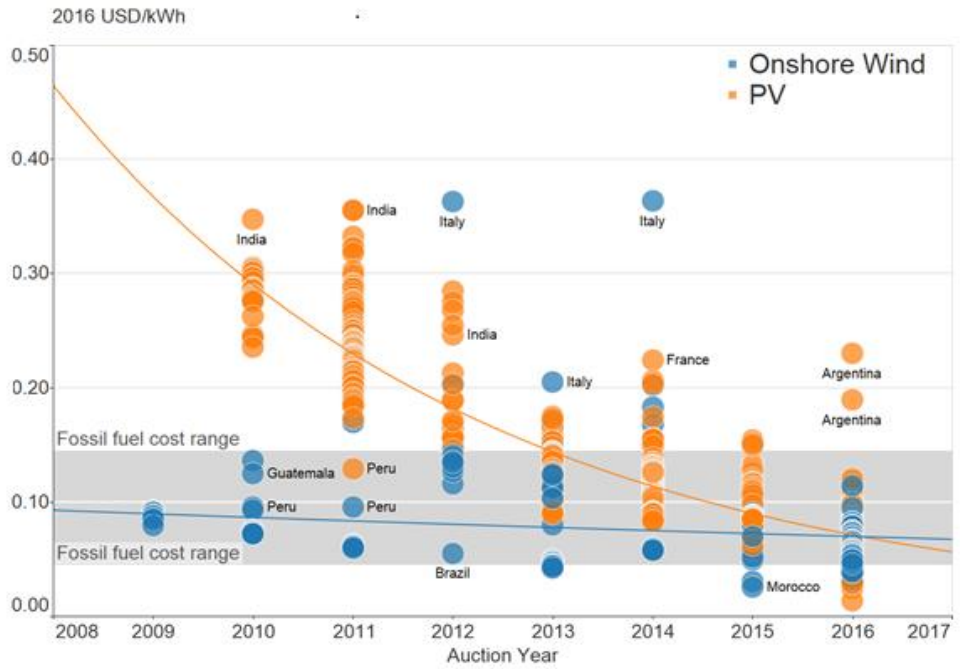
Resources and economic circumstances vary by country

Likely no “one fits all” solution

Energy transition trends

- Paris climate agreement, UN 2030 SDG objectives
- Power sector progressing well
  - As VRE shares grow new issues emerge that can be resolved
- Challenges in the end use sectors
  - Sector coupling (electrification etc)
  - Need for a sector specific global approach for industry
  - Bioenergy is key
  - Need for innovation to arrive at new affordable and scaleable solutions
- Innovation in technology, market design and regulation, business models
- Energy Transition Coalition with China, Germany, IRENA

Attractive economics
Auction and PPA price trends



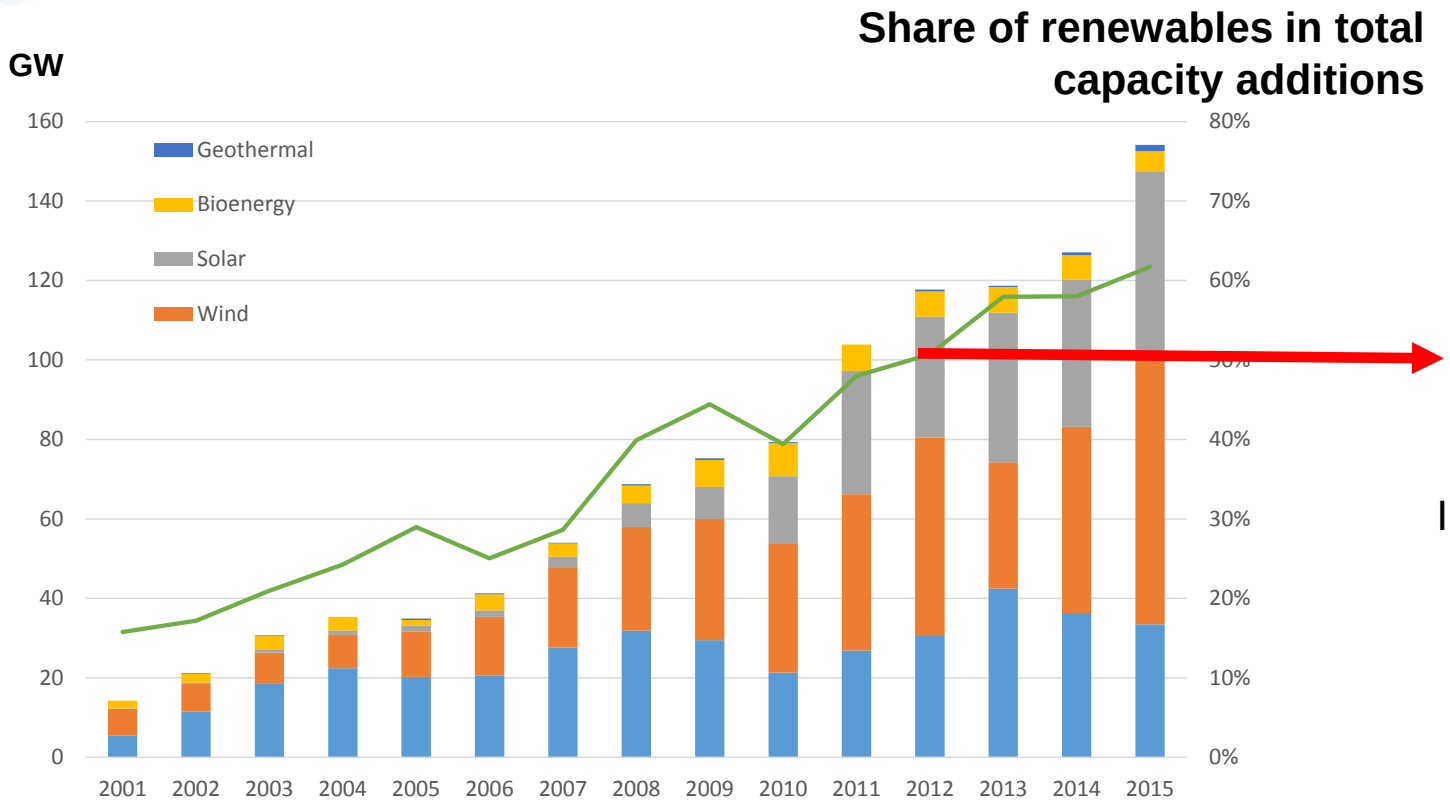
Convergence of solar PV and onshore wind prices

Project “boundaries” differ and affect the price

Projects for a wide range of technologies and locations are being offered at very low long-term contract prices

Best practice:
Concentrating Solar Power CSP @ 9.5 UScents/kWh (Dubai)
Solar PV @ 2.4 -3 UScents/kWh (Mexico, Abu Dhabi) – latest German Auction <6 UScents/kWh
Onshore wind @ 3 UScents/kWh (Morocco, Mexico)
Offshore wind @ <6 Uscents/kWh (NW Europe)

On-going power sector transformation



Since 2012 >50% of total capacity additions

2016

Installed 2006 GW RE power generation capacity

Annual RE capacity addition 161 GW

of which:

71 GW solar

51 GW wind

30 GW hydropower

9 GW biomass

Around 25% RE power generation share worldwide; growing by 0.7 percentage points per year

End use sector trends that support energy transition

- Buildings, transport sector progressing, part of industry sector is lagging

Electrification and energy efficiency

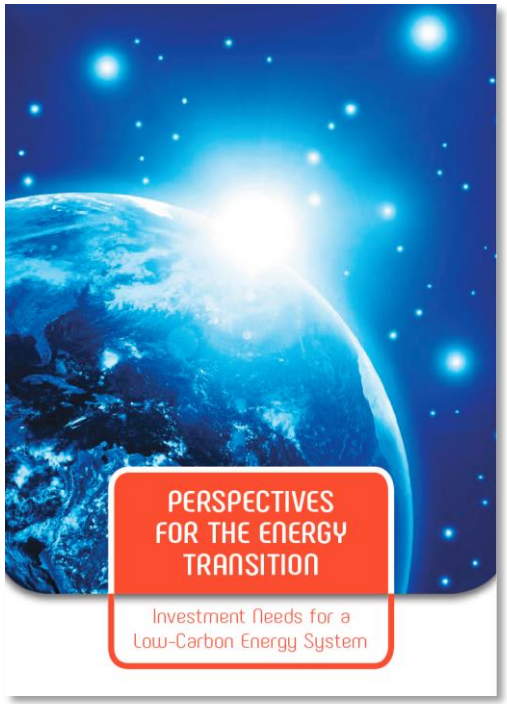
- Global energy intensity improvement has increased from 1.3%/yr to 1.8%/yr
- Global electric vehicle park doubled in 2016 to 2 million units – China growth plans for coming years
- Rapid growth heat pump deployment
- Home storage battery prices -60% in 2.5 years

Electricity grid trends

- Rapid growth off-grid and minigrid solutions
- Smart grids support high VRE shares
- A growing number of long distance UHVDC transmission lines

Perspectives for the Energy Transition

- Study at the request of German G20 Presidency
- Launched March 2017
- Informs G20 decarbonization Action Plan
- Explores the energy sector consequences of the climate agreement
- Translates Paris Agreement outcome into practicable action items
- Time horizon: 2050



March 2017

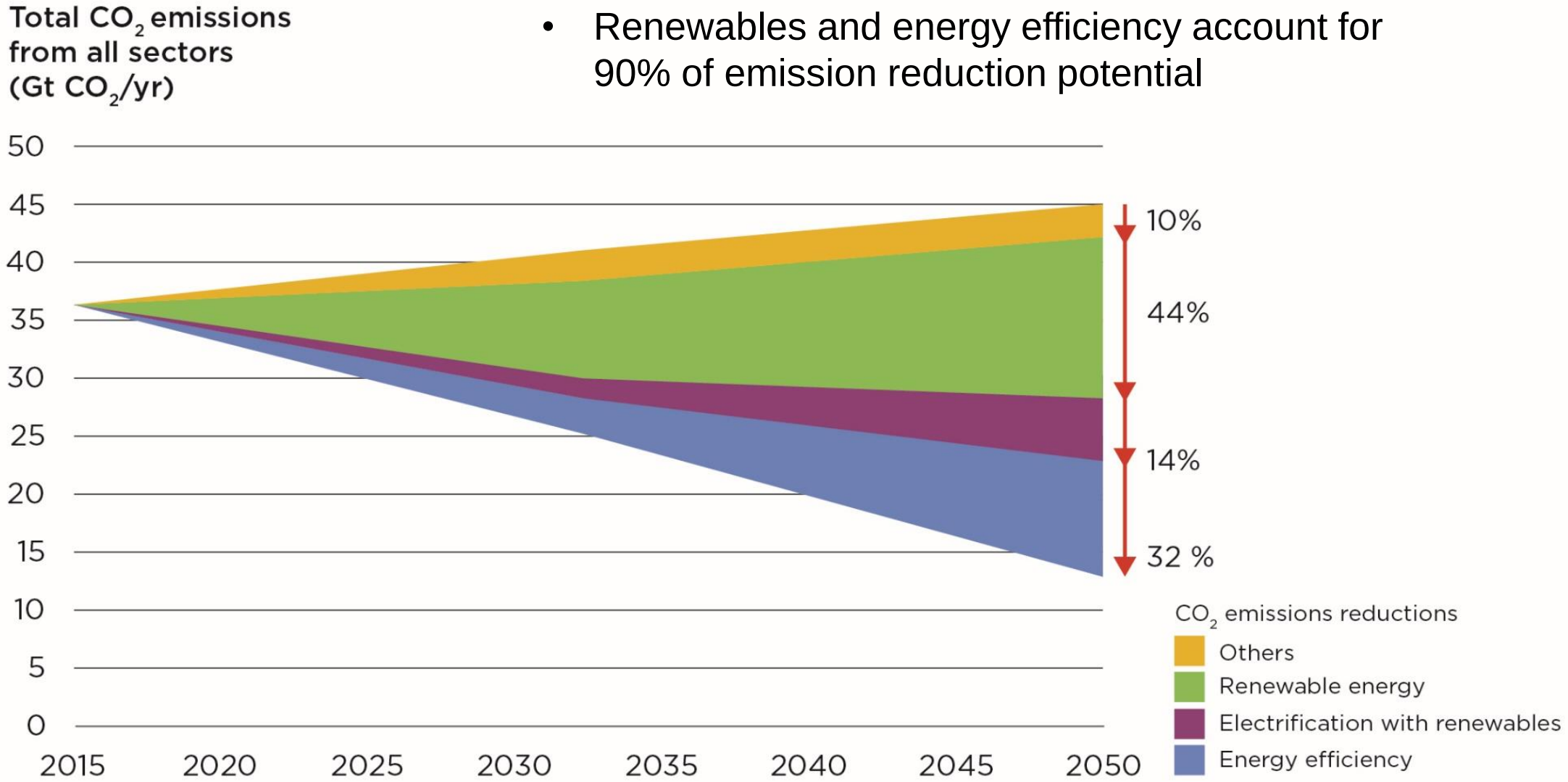
The Need for an Energy Transition - Highlights

- The Paris Agreement requires global energy decarbonization by between 2050 and 2060
- Global energy CO_2 emissions to fall by 70% between 2015 and 2050, while GDP nearly triples
- This requires an energy transition, largely based on renewable energy and energy efficiency
- The share of renewables needs to reach 2/3 of energy supply by 2050
  - Growth to increase seven-fold to 1.2%/yr
- This transition is technically feasible and economically beneficial
  - Health and climate benefits exceed the cost by a factor of 2-6
  - Additional investments of USD 29 trillion from now till 2050 (+USD 0.8 trln/yr)
  - Global GDP will increase by 0.8% in 2050
  - Renewables alone can support 26 million jobs in 2050, from roughly 9 million today.

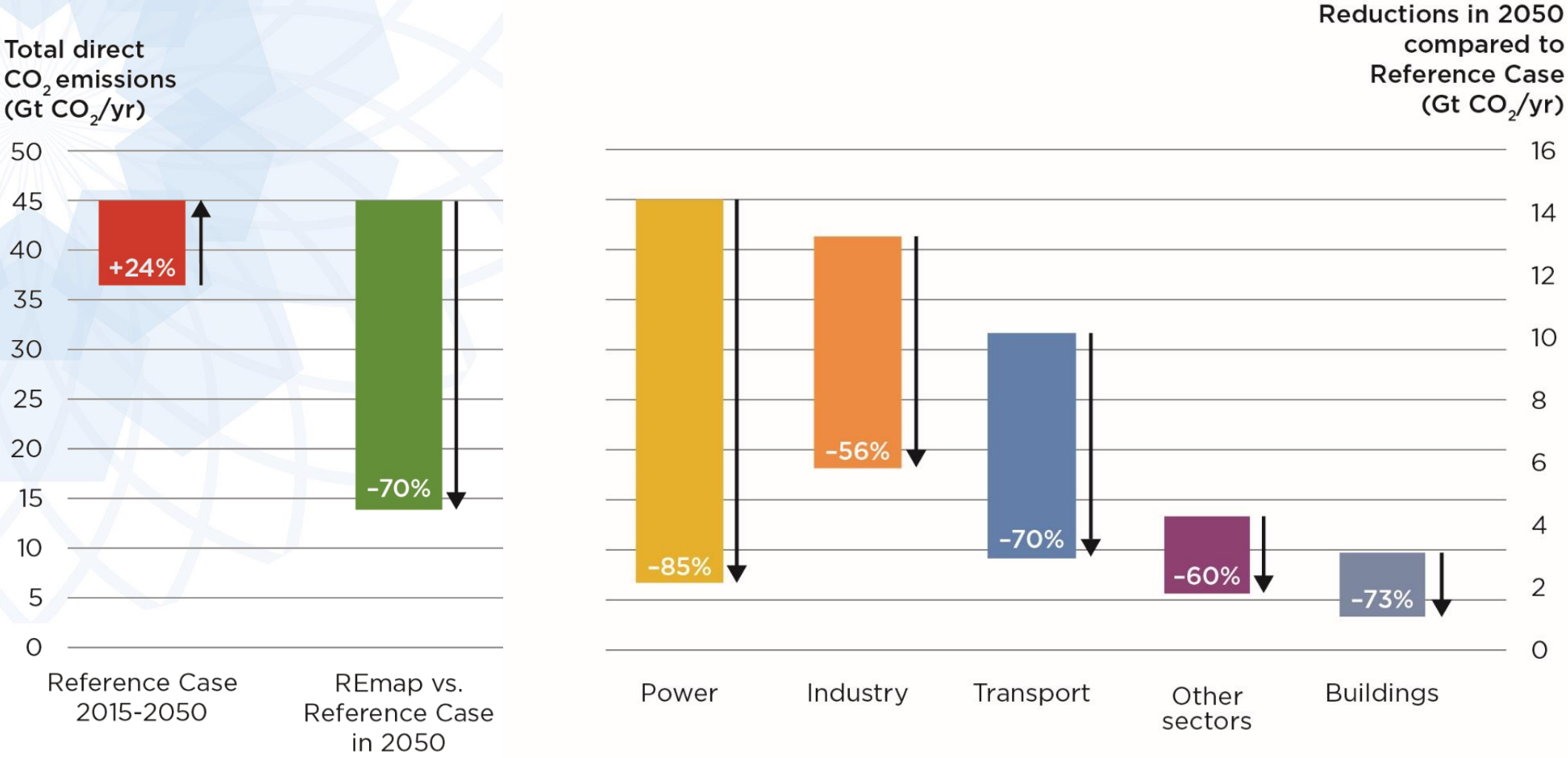
Reducing global CO_2 emissions in the energy sector

(energy + process emissions)

- Renewables and energy efficiency account for 90% of emission reduction potential



Key global emissions reduction by sector

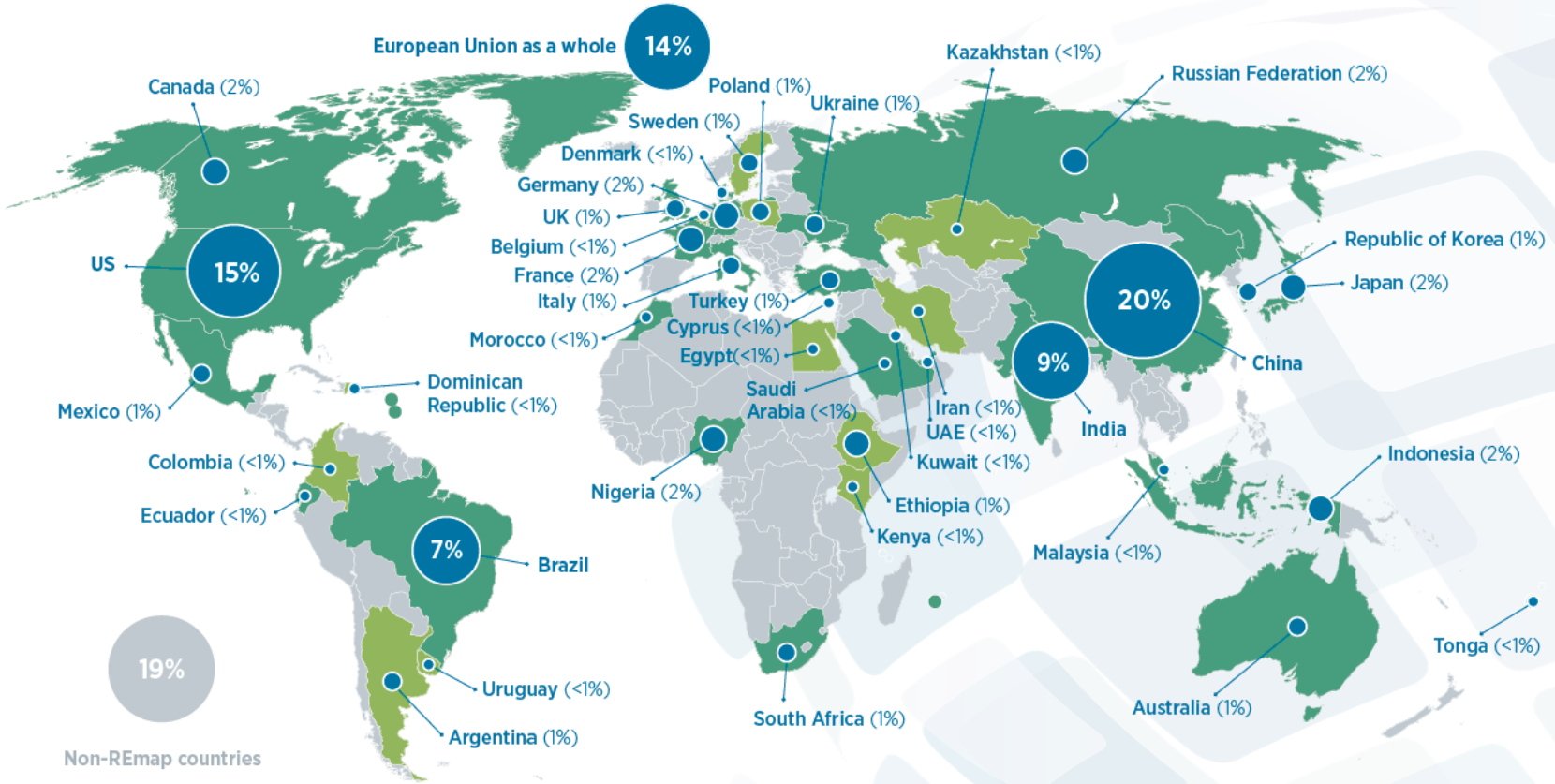


- By 2050 energy-related CO_2 emissions will need to decrease to below 10 Gt.
- CO_2 emissions from the power and buildings sectors will be almost eliminated.
- Industry and transport would be the main sources of emissions in 2050.

Europe, a key contributor to doubling RE by 2030

#REmap

Ambitious European targets for 2030 are key



Note: Percentages indicate how much renewable energy each country consumes of the global total in 2030 if the REmap Options are deployed.

What do we need for a successful energy transition ?

- Global action based on an economic rationale – enabling frameworks
- Much higher efficiency of all things new and buildings retrofit
- Seven-fold increase of modern RE deployment growth
- Close to zero carbon emissions in the power sector
- Double electrification of end uses (building, industry, transport)
- Double bioenergy use, especially in end use sectors
- Perhaps hydrogen for some niche applications
- A binding global sectoral approach for energy intensive manufacturing industry
- A binding global approach for aviation and shipping
- Innovative technology solutions for part of transport, heavy industry
- Energy prices that reflect climate and health impacts
- Much more ambitious NDCs by 2020

IRENA

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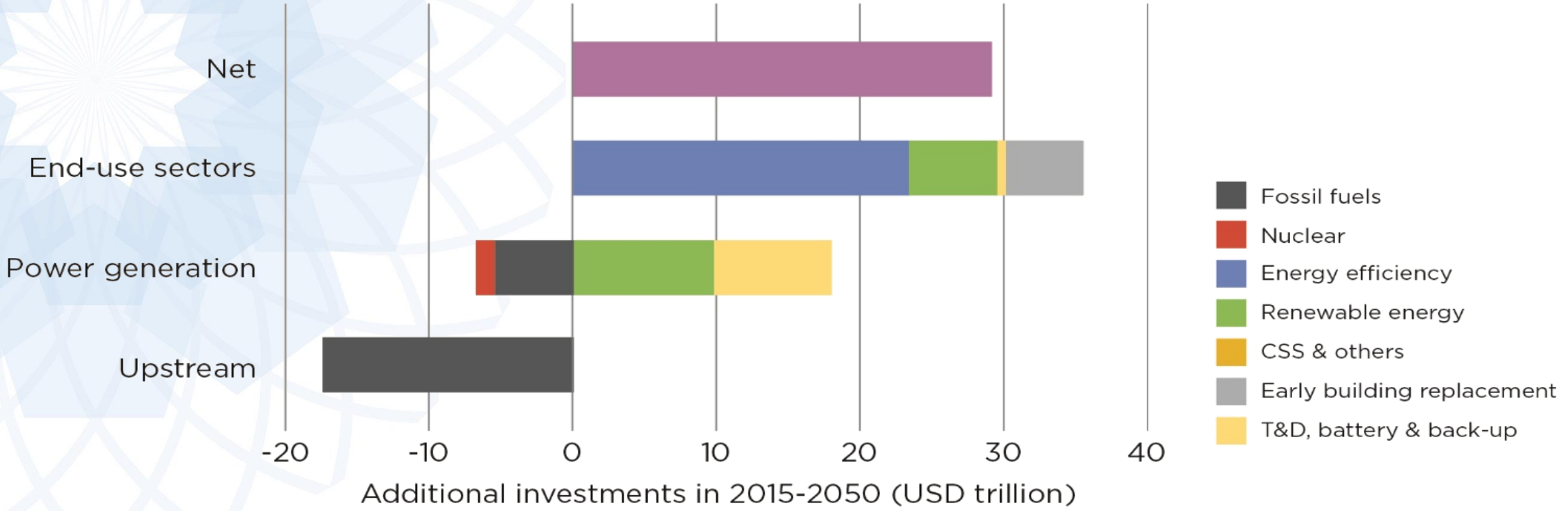
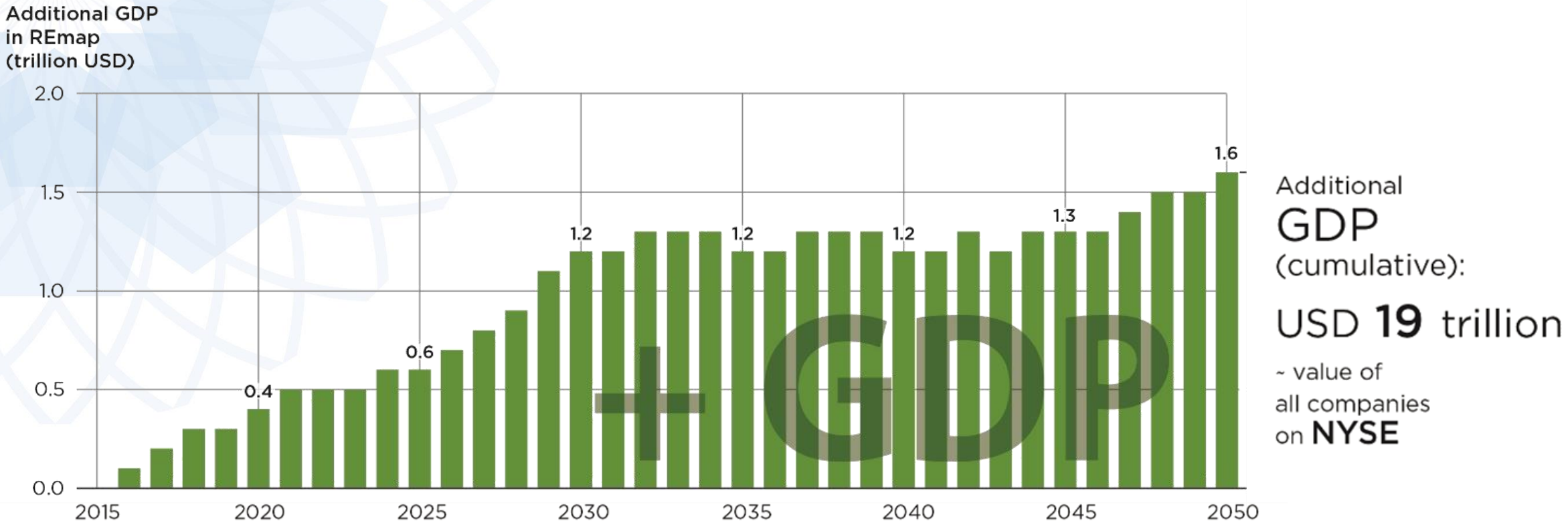
Additional investment needs



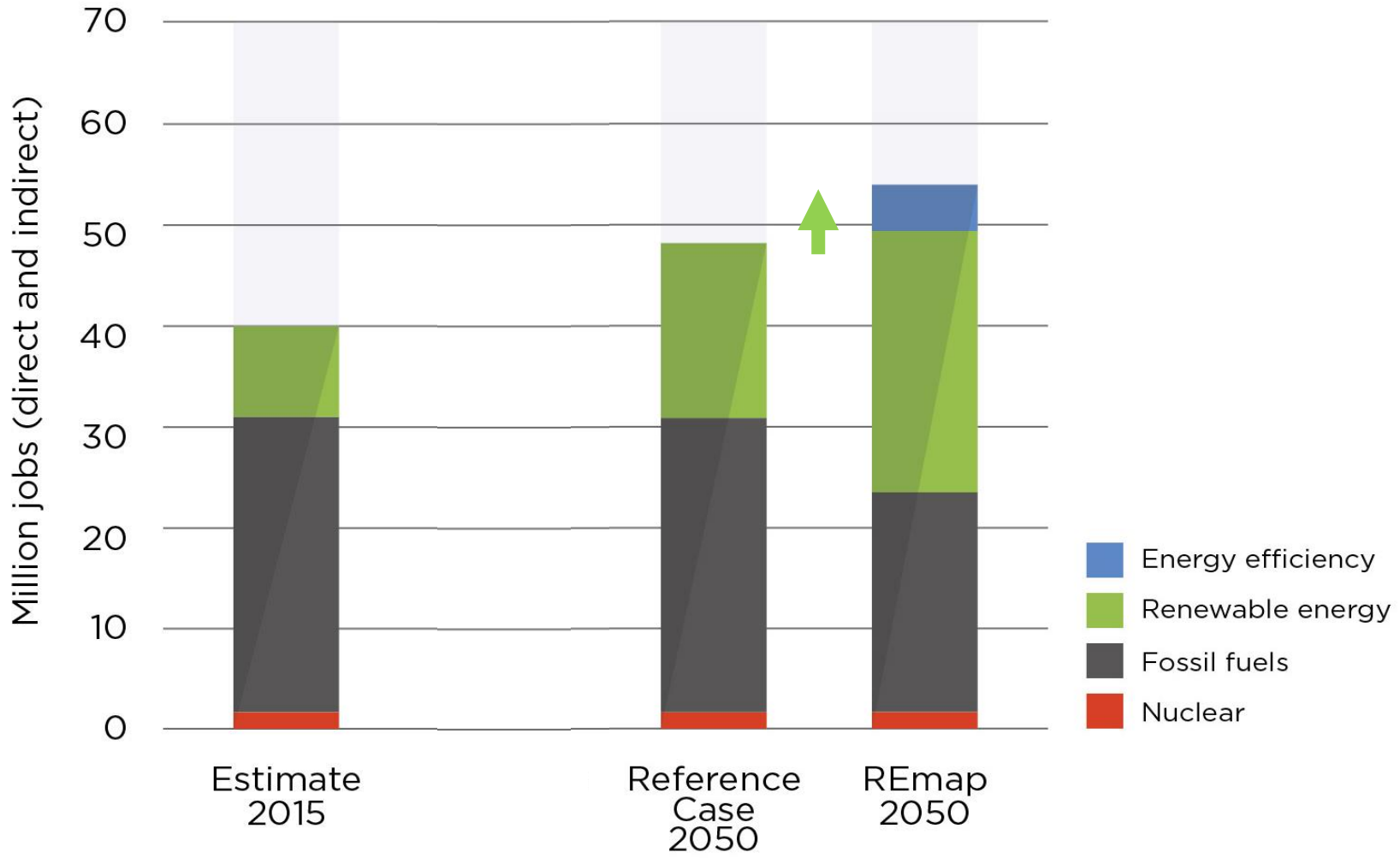
- Until 2050 the transition requires investing an additional USD 29 trillion (compared to Reference Case)
  - Less than 1% of global GDP per year.
- The largest additional investment needs are in energy efficiency, followed by renewables.
- The total investment requirements, however, are reduced by the avoided investments in fossil fuels upstream and conventional power generation.

Global GDP impacts of the REmap energy transition: additional



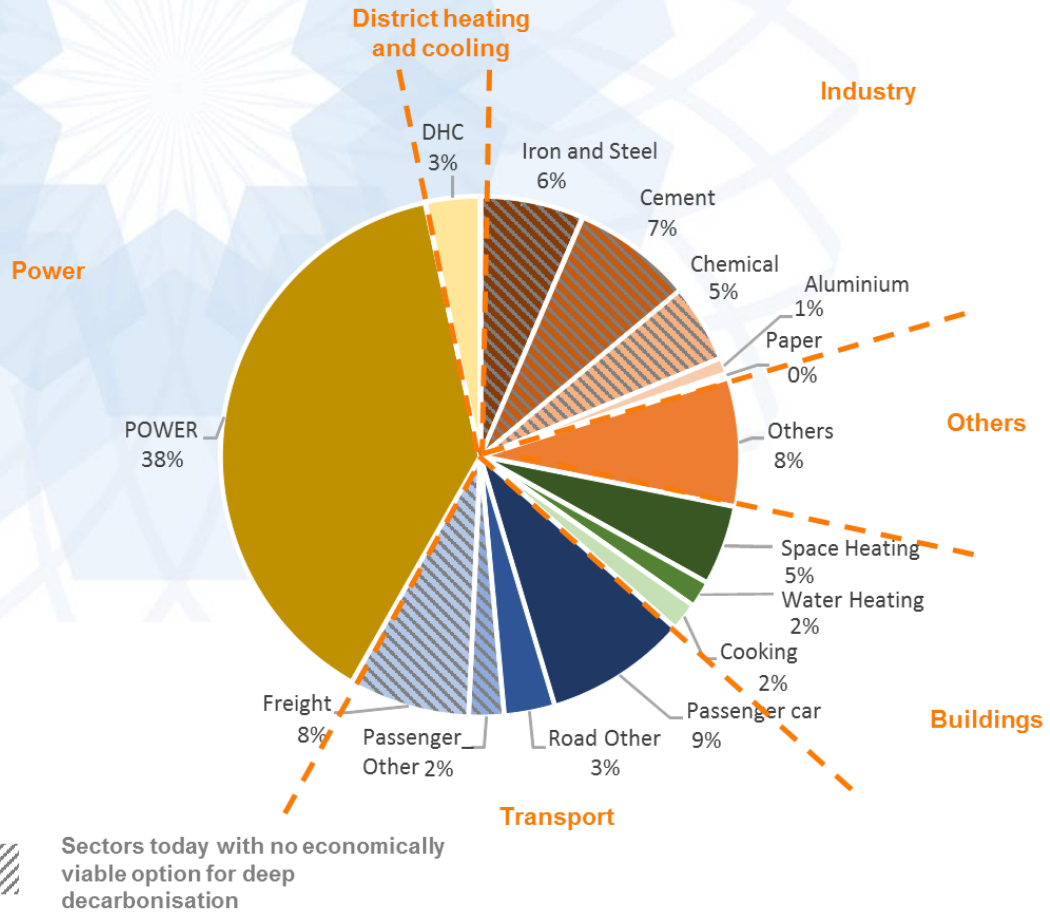
In cumulative terms this constitutes almost USD 19 trillion in increased economic activity between today and 2050.

The transition creates jobs



New jobs in renewables and energy efficiency more than offset job losses in fossil fuel sectors.
Renewable jobs reach 26 million in 2050, from over 9 million today
GDP improvement induces further job creation in other economic sectors

Innovation Challenges



Around one third of energy-related emissions in the Reference Case in 2050 currently have no economically viable options for decarbonisation

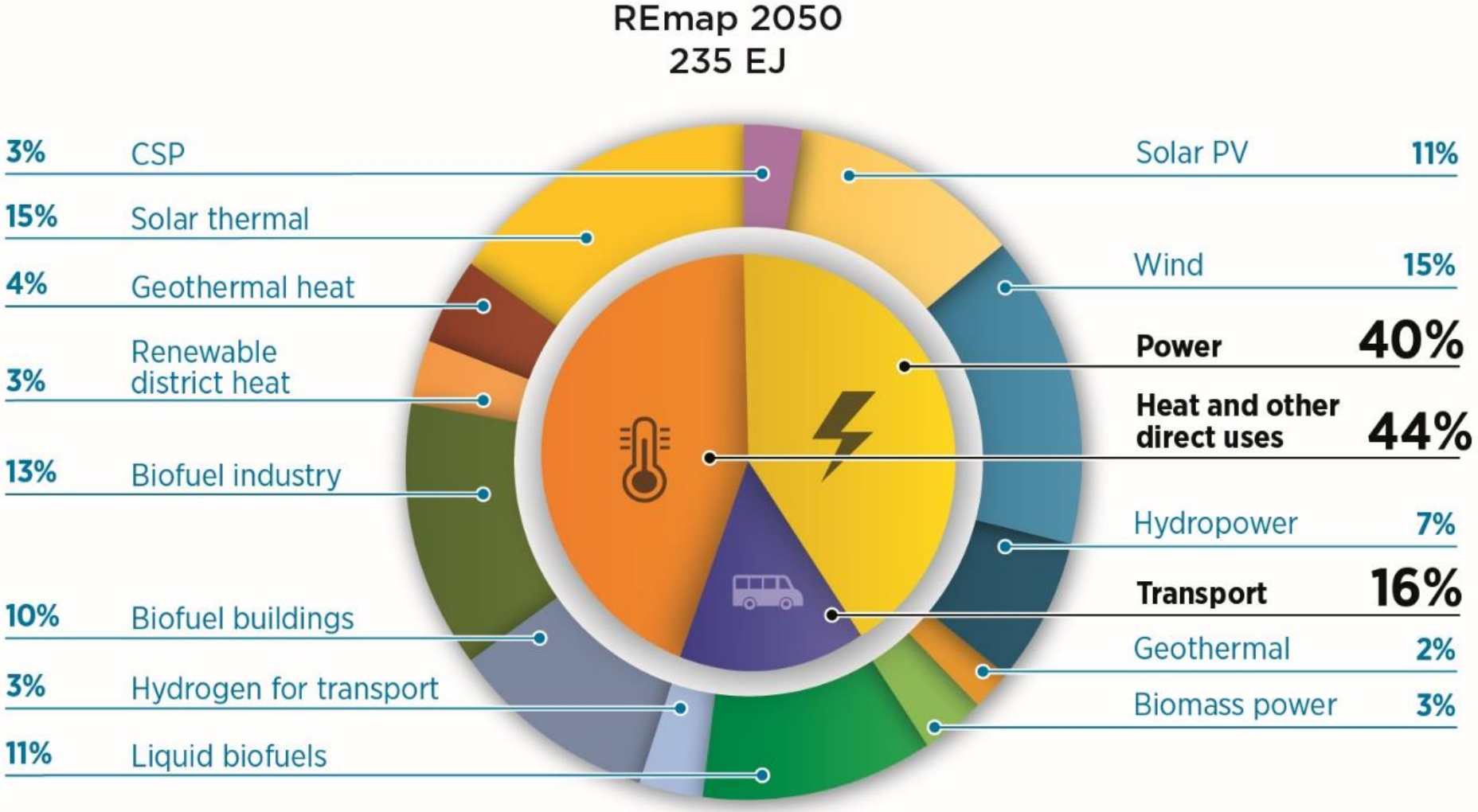
IRENA
International Renewable Energy Agency

New Analysis – launched today

Policy Implications

- **Deep emission cuts in the power sector** are needed and require sound policy frameworks and market designs to achieve a flexible and resilient system.
- Enact **policies targeted at end-use sectors** (e.g. renewables for heating and cooling and transport, sector coupling, holistic approach, synergies with energy efficiency).
- Need for adequate **energy pricing**, including pricing of externalities (e.g. carbon emissions).
- **Need to accelerate innovation** to allow time for developing the fundamental new solutions for different sectors and processes, ahead of long investment cycles.
- **A comprehensive approach to policymaking** is needed, including energy, climate and broader economic policies.

Final renewable energy use by sector and technology in REmap



Under REmap, final renewable energy use is four-times higher in 2050 than it is today.

Power and heat consume about 40% and 44% of the total renewable energy, respectively, while transport uses about 16%.