

# GLOBAL ENERGY TRANSFORMATION



A ROADMAP TO  
**2050**

# About IRENA

Established in 2011.

160 Members; 23 States in accession.

**Mandate:** to promote the **widespread adoption and sustainable use of all forms of renewable energy**

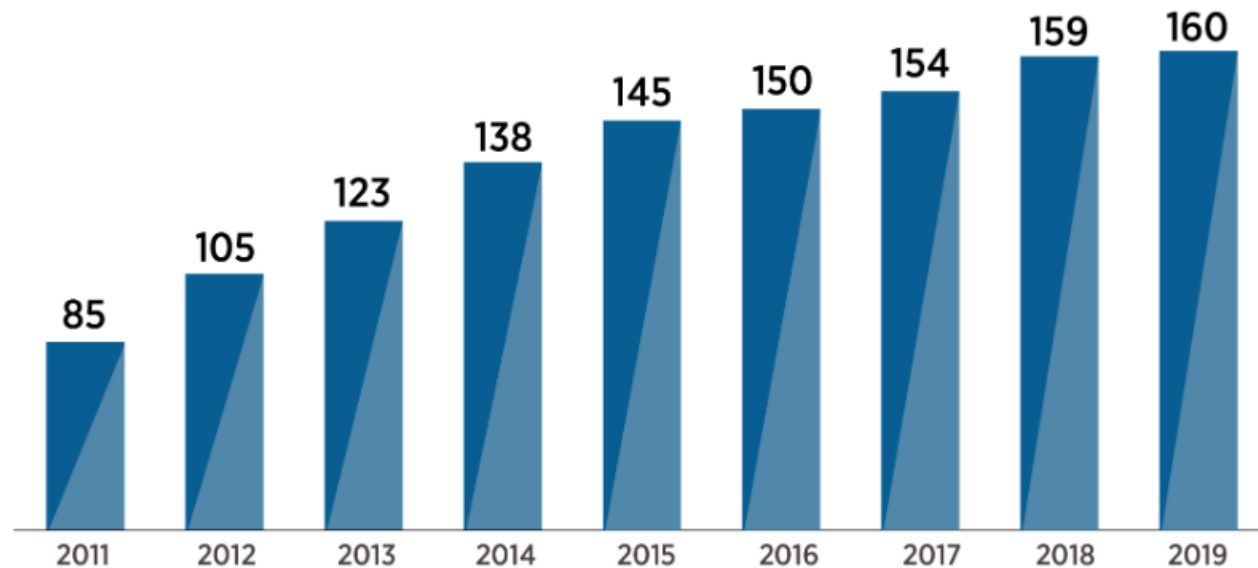
**Scope:** All renewable energy sources produced in a **sustainable manner**

**IRENA serves as:**

- Centre of excellence for knowledge and innovation
- Global voice of renewables
- Network hub
- Source of advice and support



Growth in IRENA Membership



## IRENA Offices



IRENA Headquarters

Masdar City  
PO Box 30001, Abu Dhabi



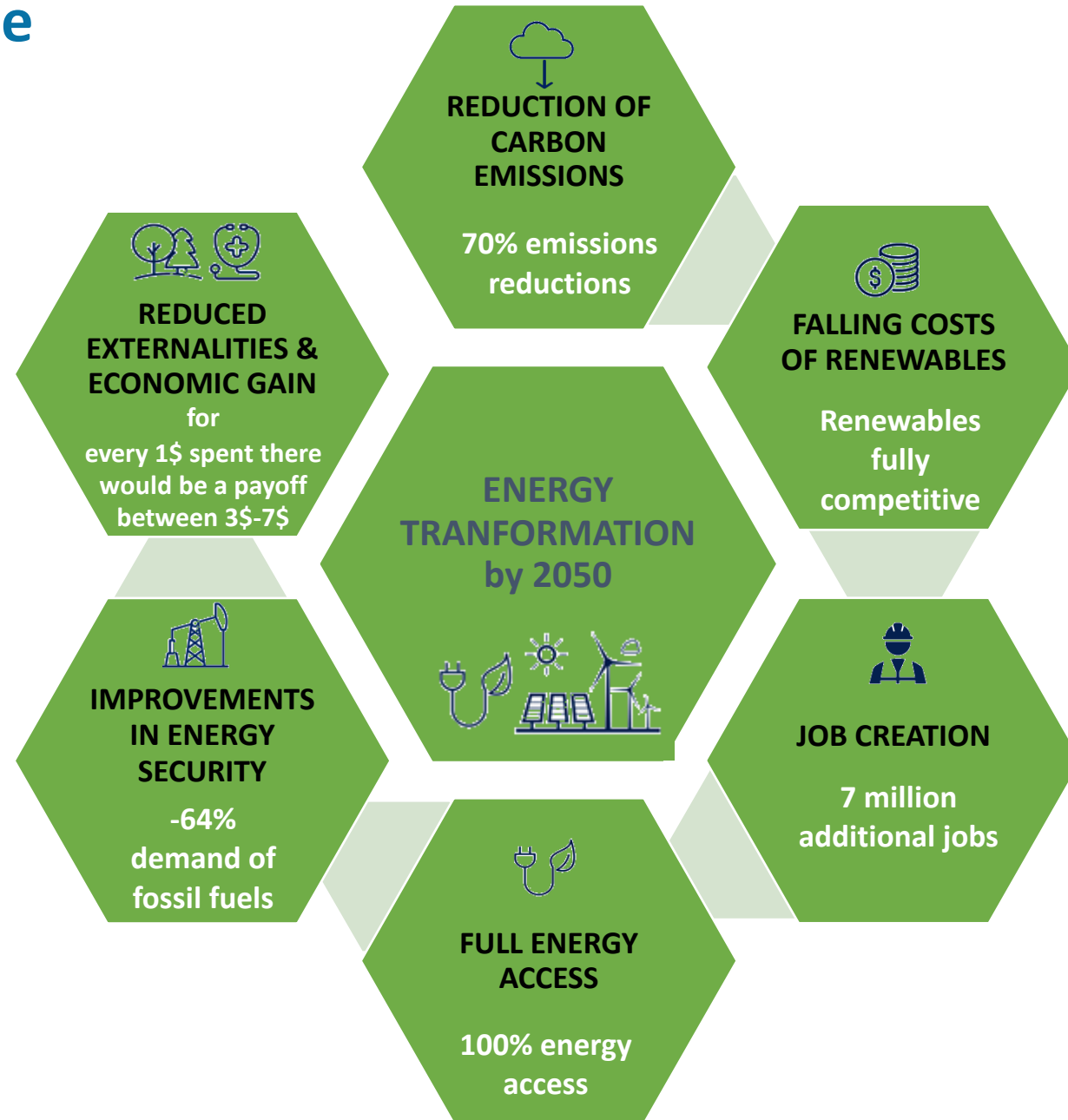
IRENA Innovation and Technology  
Center



IRENA - Office of the Permanent  
Observer to the United Nations

# Drivers for the energy transition: the role of renewable

- Local pollution, per capita emissions, floods
- Economy diversification: GDP dependence from oil&gas industry



- Competitiveness, decreasing costs of renewables, fostering green growth
- Income and quality - jobs

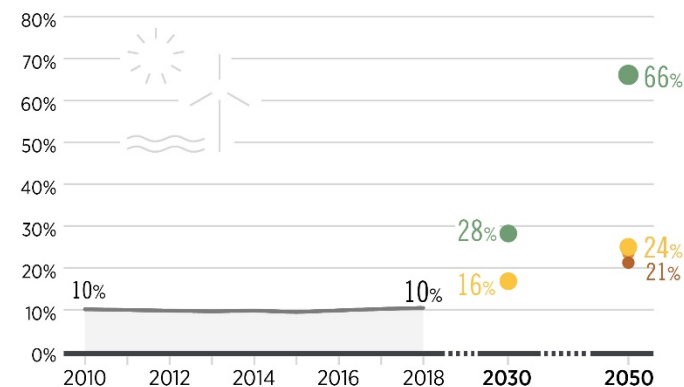
# What's happening now?

- Limited energy transition progress during the past decades
- GHG emissions continue to rise while 1.5 degrees becomes more pertinent
- Global energy transition needed in the coming 30 years – much faster than before
- Disagreement on how such a transition can be achieved and what it should look like
  - 2 degrees or 1.5 degrees, and their Gt CO<sub>2</sub> pathway implications
- Complex questions:
  - CCS/CCUS uses and costs, Nuclear costs, “clean” coal, LNG and fuel switching
  - Solar PV and wind are cheap, now what?
  - Role of hydrogen and PtX: potentially very important but uncertain; electrification and batteries; biofuels
- Specific sectors with particular challenges: Aviation, shipping, petrochemicals, cement, etc.
- Energy transition will have a profound impact on fossil fuel supply and demand

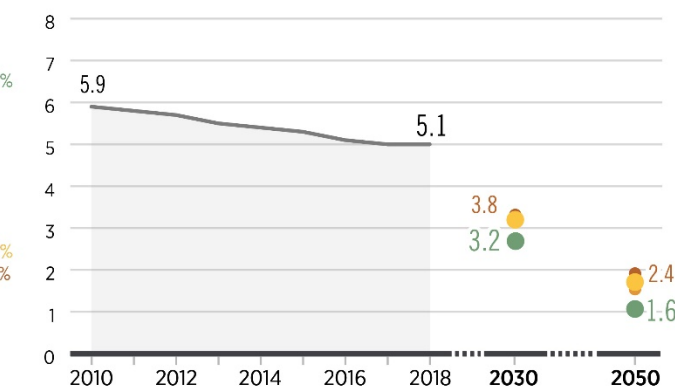


# Monitoring the energy transition, mixed indicators

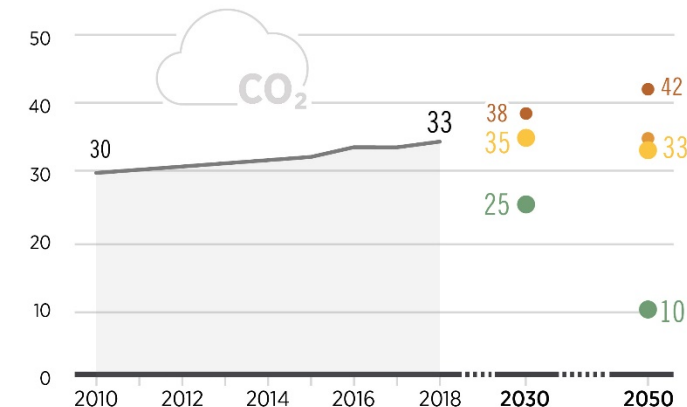
Renewable energy share in total final energy consumption (TFEC, %)



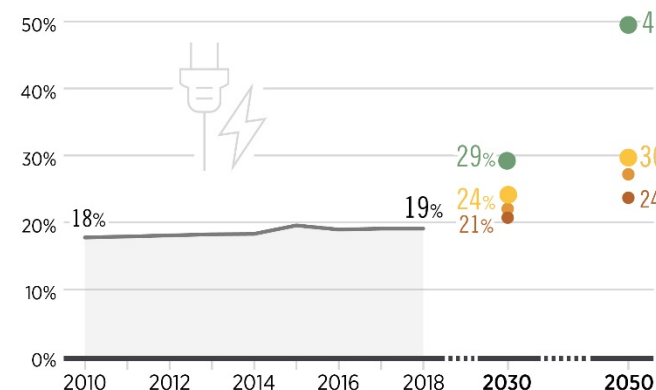
Energy intensity of GDP, based on TPES (MJ/USD-PPP, 2011)



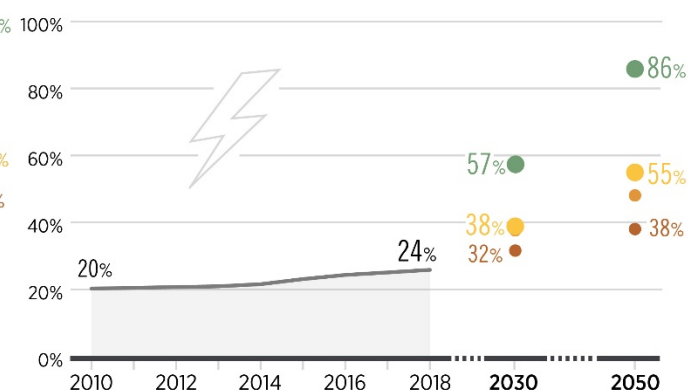
Annual emissions from the energy sector (Gt CO<sub>2</sub>/year)



Electricity share of TFEC (%)



Renewable energy share in electricity generation (%)



- Historical
- REmap
- Reference Case - 2019 analysis
- Reference Case - 2018 analysis
- Reference Case - 2017 analysis

**Current plans – as reflected in Nationally Determined Contributions to meet climate goals – point in the right direction yet still fall short of what is needed to meet international climate goals. Serious action is needed to accelerate the energy transition.**

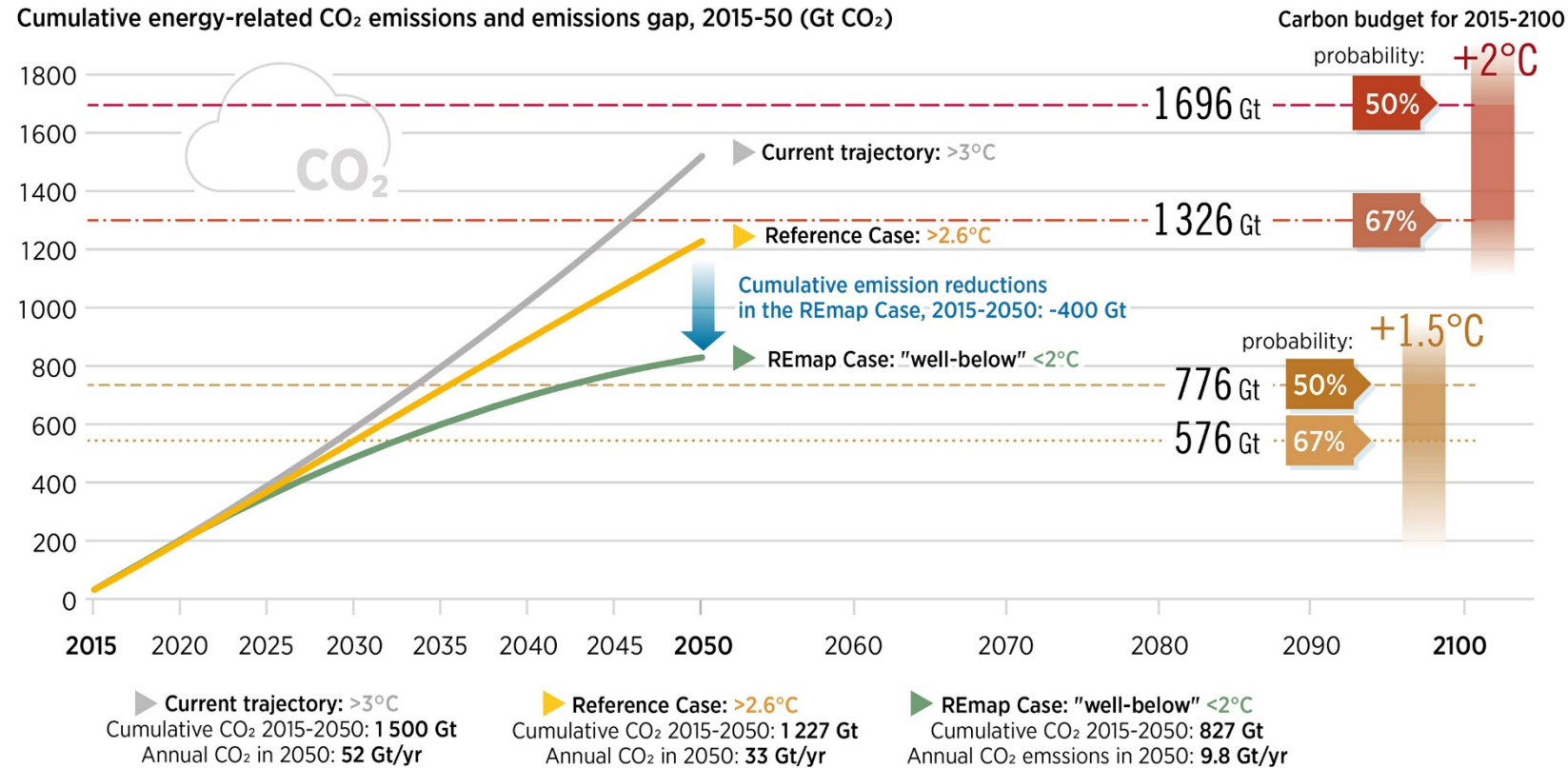
# IRENA's energy transition series

- One of IRENA's flagship publications.
- **Third edition** launched at the Berlin Energy Transition Dialogue 2019.
- Joint report of IRENA's **Renewable energy roadmaps (REmap) programme** of Innovation and Technology Centre (IITC) and **socio-economic footprint of Knowledge, Policy and Finance Centre (KPFC)**.
- However main focus of REmap **efforts are renewable energy and energy transition roadmaps** for regions and countries, currently completed/ongoing roadmaps for **15 countries, 5 regions**



# PATHWAY FOR THE TRANSFORMATION

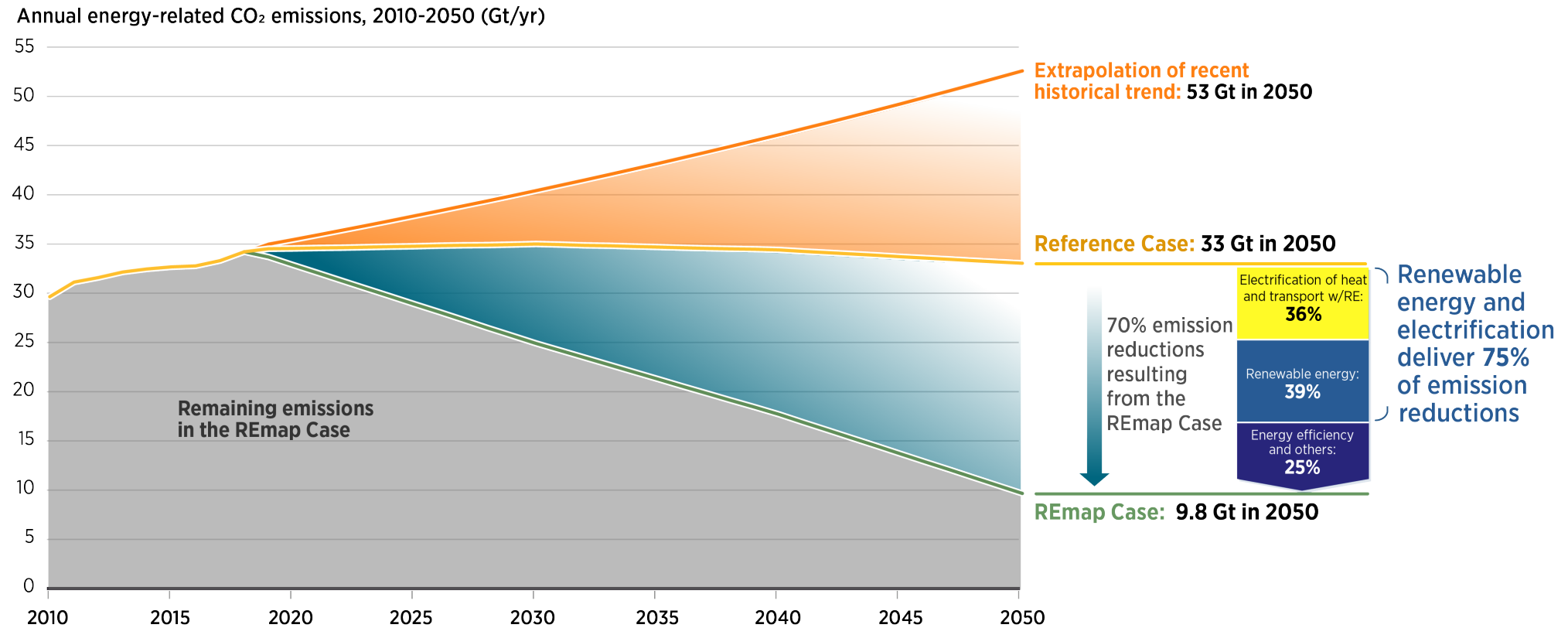
# Bridging the gap: A pathway for a well-below 2°C climate target, towards 1.5°C



- The **global carbon budget** is set to run out by 2030 based on current and planned policies.
- **Energy-related emissions would need to fall by 3.5% per year** to the world to meet the **Paris Agreement**.

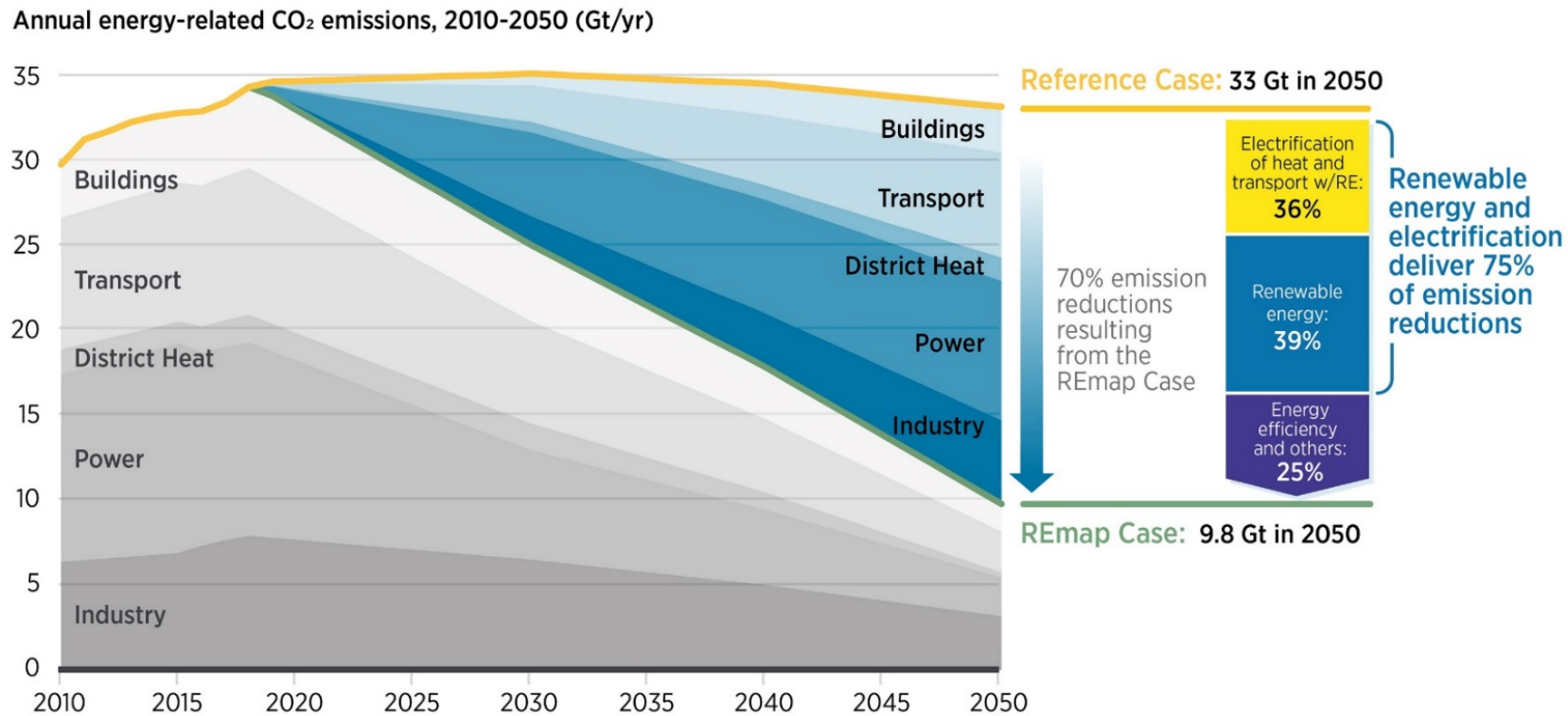
Notes: 1) Taking into account 2015-2017 emissions on top of the budget provided in IPCC (2018) (Table 2.2 – with no uncertainties and excluding additional Earth system feedbacks); 2) Budgets exclude industrial process emissions of 90 Gt; for this study, the assumption is that CO<sub>2</sub> emissions from land use, land-use change and forestry (LULUCF) fall from 3.3 Gt in 2015 to zero by mid-century. LULUCF subsequently becomes a net absorber of CO<sub>2</sub> over the remainder of the 21st century, and, as a result, cumulative CO<sub>2</sub> emissions from LULUCF between 2015 and 2100 are close to zero; 3) Current trajectory shows the recent historical trend line, assuming the continuation of the annual average growth in energy-related CO<sub>2</sub> emissions from the last five years (2013-2018) of 1.3% compound annual growth up to 2050; 4) Emissions budgets represent the total emissions that can be added into the atmosphere for the period 2015-2100 to stay below 2°C or 1.5°C at different confidence levels (50% or 67%) according to the IPCC (2018) report.

# Recent trends vs. Reference Case vs. REmap



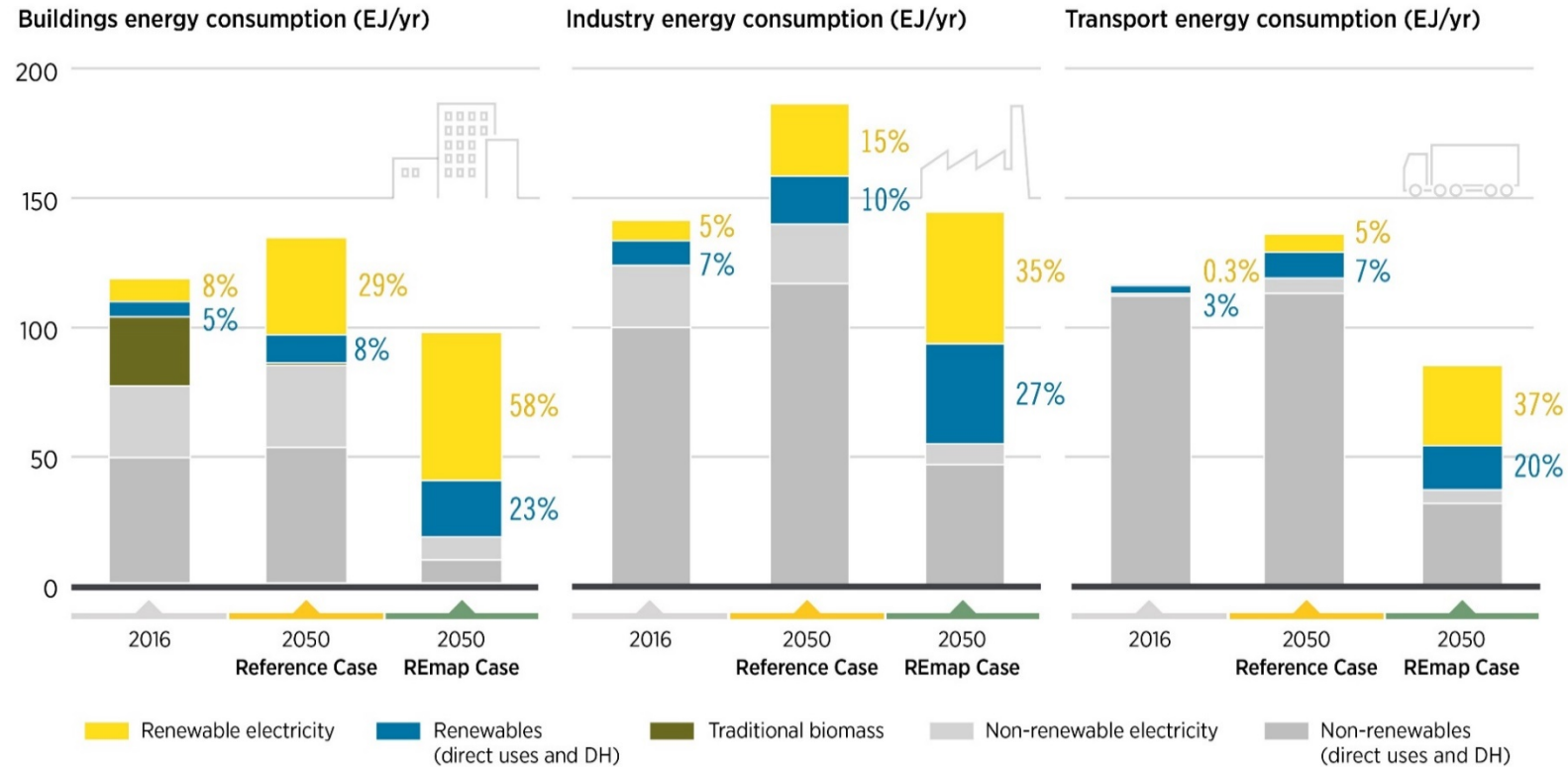
- Annual energy-related CO<sub>2</sub> emissions could range from **10 Gt to over 50 Gt by 2050**

# Key enabling solutions: Renewables and energy efficiency, boosted by substantial electrification



- Annual energy-related **CO<sub>2</sub> emissions under current and planned policies** – the Reference Case – are expected to remain **flat** but **must be reduced by 70%** to bring temperature rise to the **well-below 2°C climate goal**.
- **Electrification, renewable energy and energy efficiency** measures provide over **90%** of the reductions required by 2050. **Renewable power and electrification of heat and transport alone reduce emissions by 75%.**

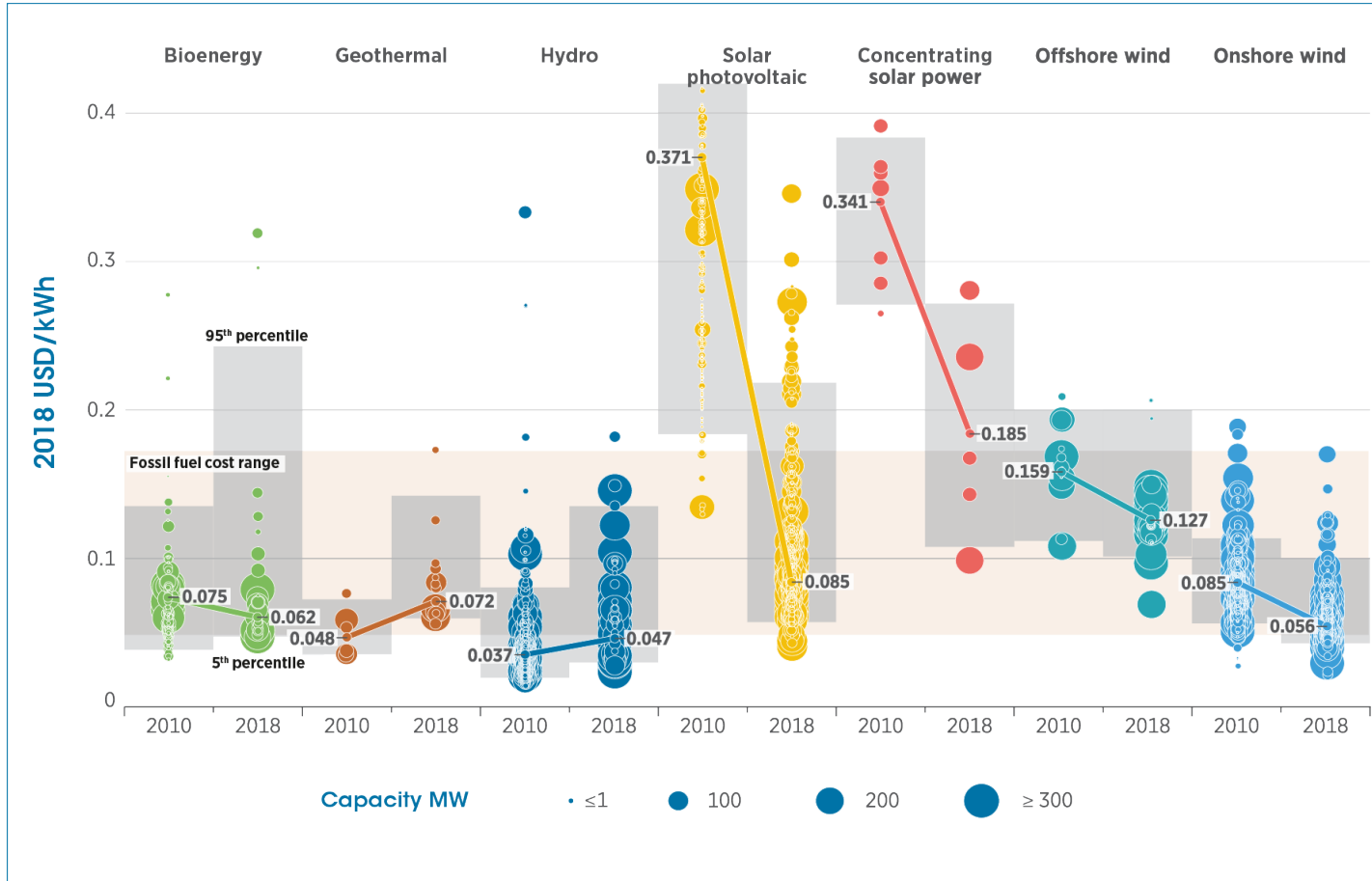
# Renewable energy shares increase in all end-use sectors



- By 2050, renewables could dominate the transport and buildings sectors reaching 57% and 81% of the sectors' final energy consumption.
- Electricity would account for the largest share of renewable energy use, complemented by biomass, geothermal and solar thermal.



# Renewable Energy: Recent cost evolution

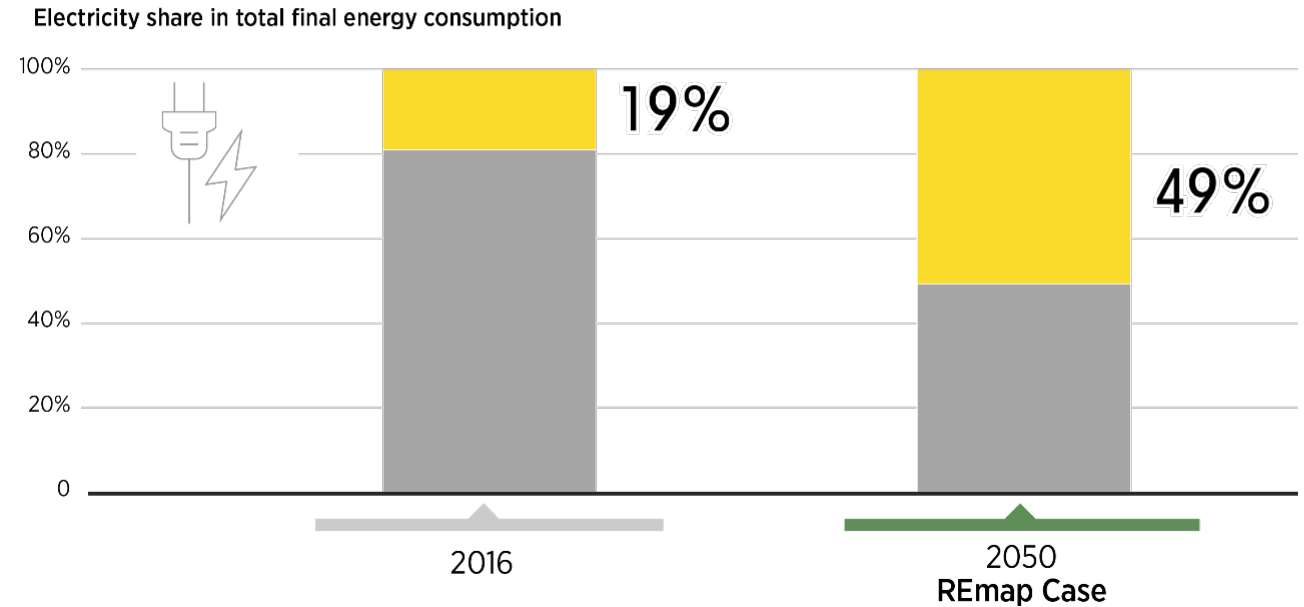
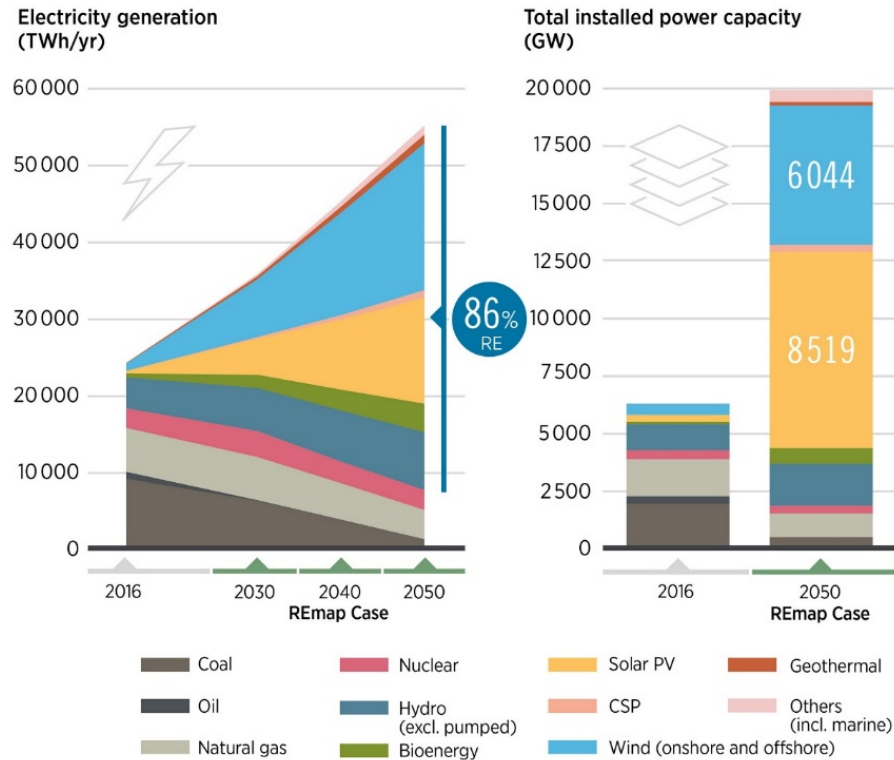


**Note:** This data is for the year of commissioning. The diameter of the circle represents the size of the project, with its centre the value for the cost of each project on the Y axis. The thick lines are the global weighted-average LCOE value for plants commissioned in each year. Real weighted average cost of capital (WACC) is 7.5% for OECD countries and China and 10% for the rest of the world. The single band represents the fossil fuel-fired power generation cost range, while the bands for each technology and year represent the 5th and 95th percentile bands for renewable projects.

- **Average LCOE of all renewable power generation technologies, except CSP fall in fossil fuel cost range**
- Bioenergy, geothermal, hydro and onshore wind all at lower end of fossil cost range
- Solar PV rapidly falling towards lower end.
- Offshore wind and CSP have much lower deployment. Data suggests costs will continue to fall.



# Electrification paired with renewables is a major solution for decarbonisation



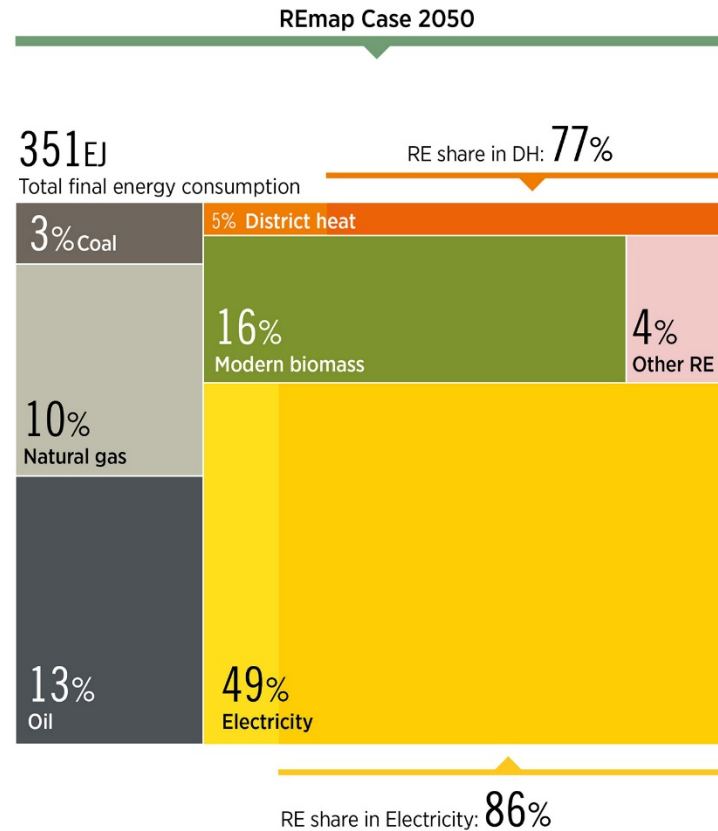
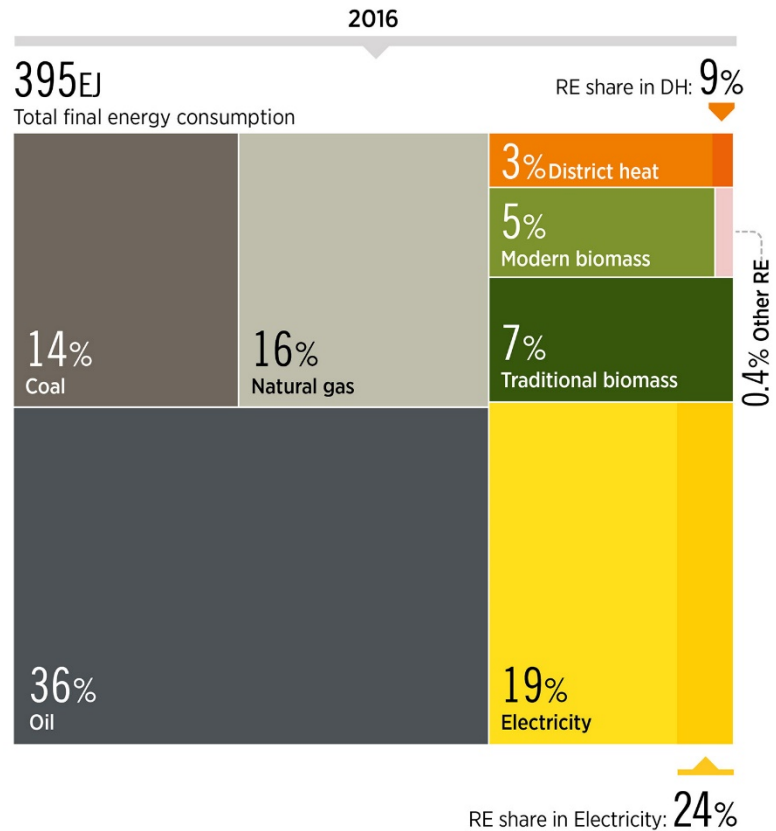
## By 2050:

- Electricity becomes the central energy carrier
- 86% of electricity generation will come from renewables

**A transformed energy system: Scaling up renewables not just for power, but also for heat and transport**

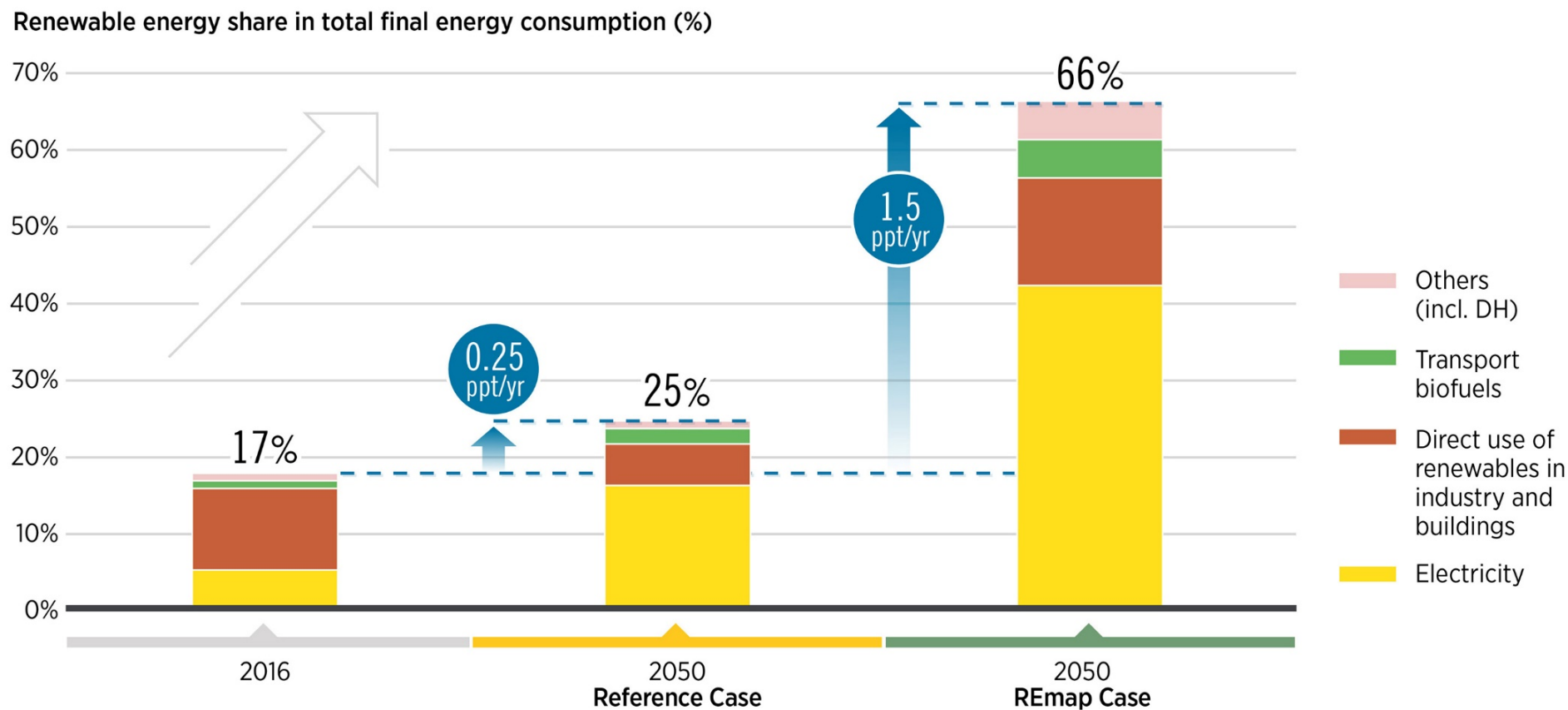
# An electrified future: Electricity becomes the central energy carrier

Total final energy consumption breakdown by energy carrier (%)



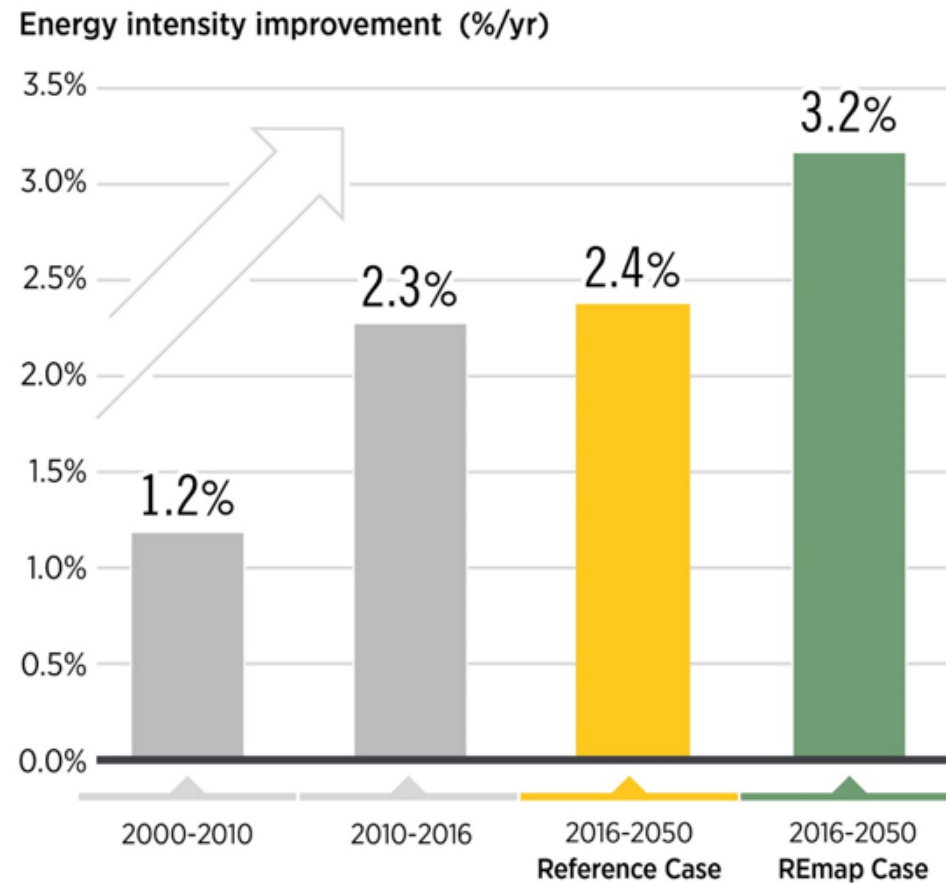
- Scaling up electricity from renewables will be crucial for the decarbonisation of the world's energy system.

# A transformed energy system: Renewables growth must increase six-fold



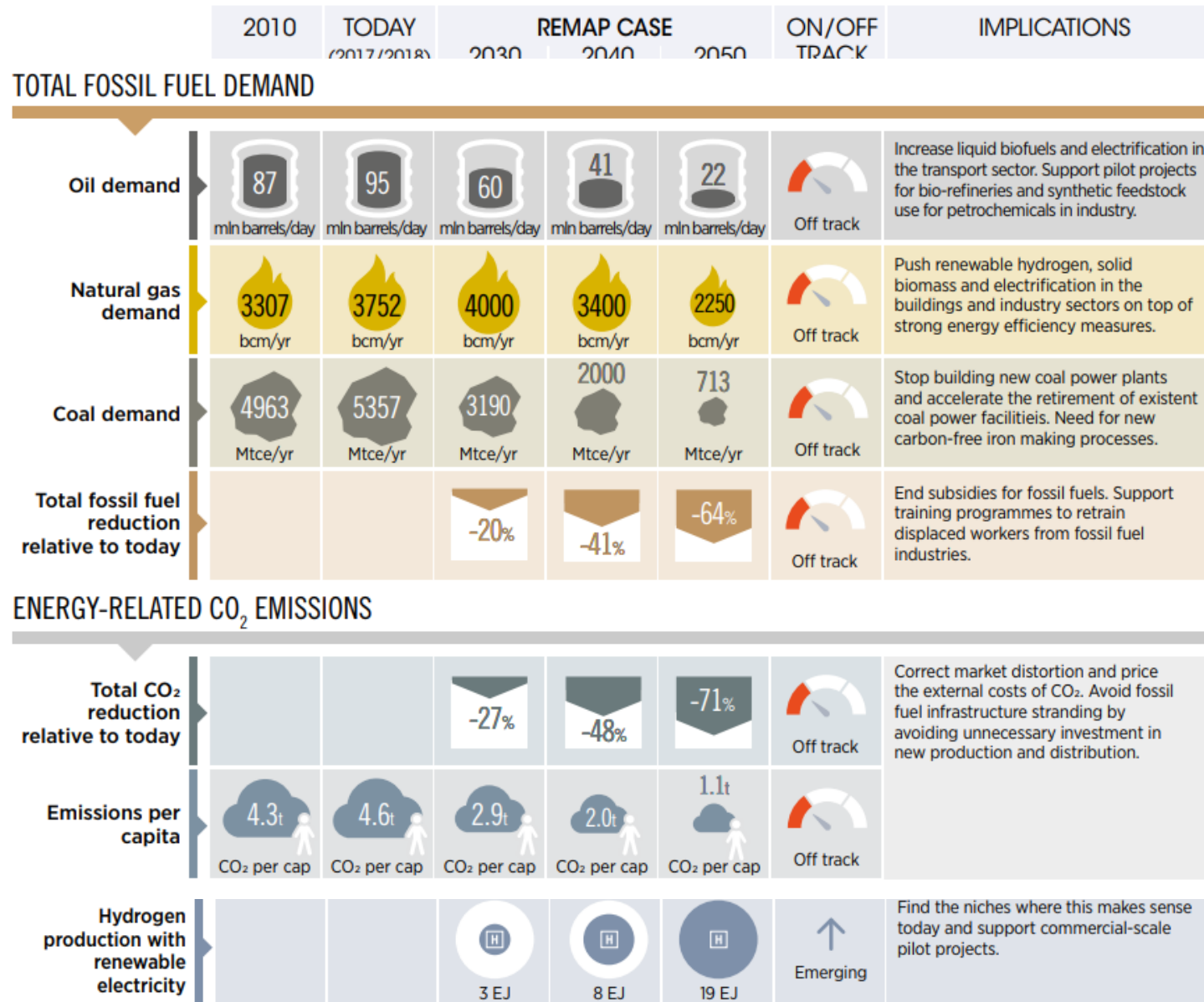
- The share of renewables in the world's total final energy consumption has to increase six times faster to meet agreed climate goals.

# A transformed energy system: Energy intensity improvement needs to increase by a third, to 3.2% per year



- Energy intensity can be improved by: - Scaling up solar, wind and other renewables, - improving energy efficiency, - electrifying transport and heat, - structural change in transport and industry.

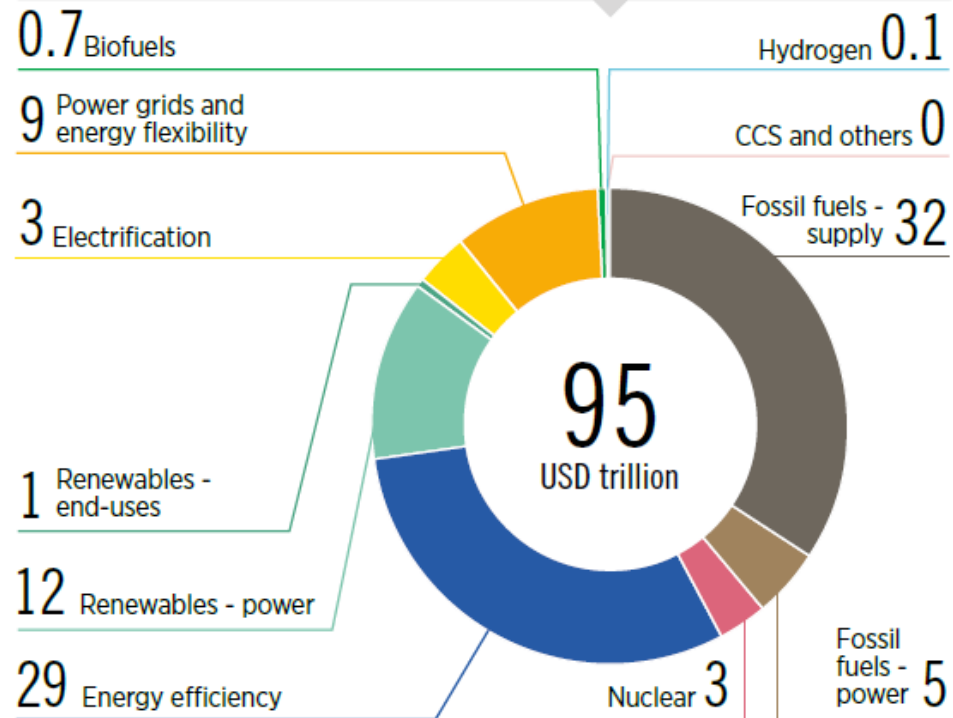
# Tracking progress to achieve the global energy transformation



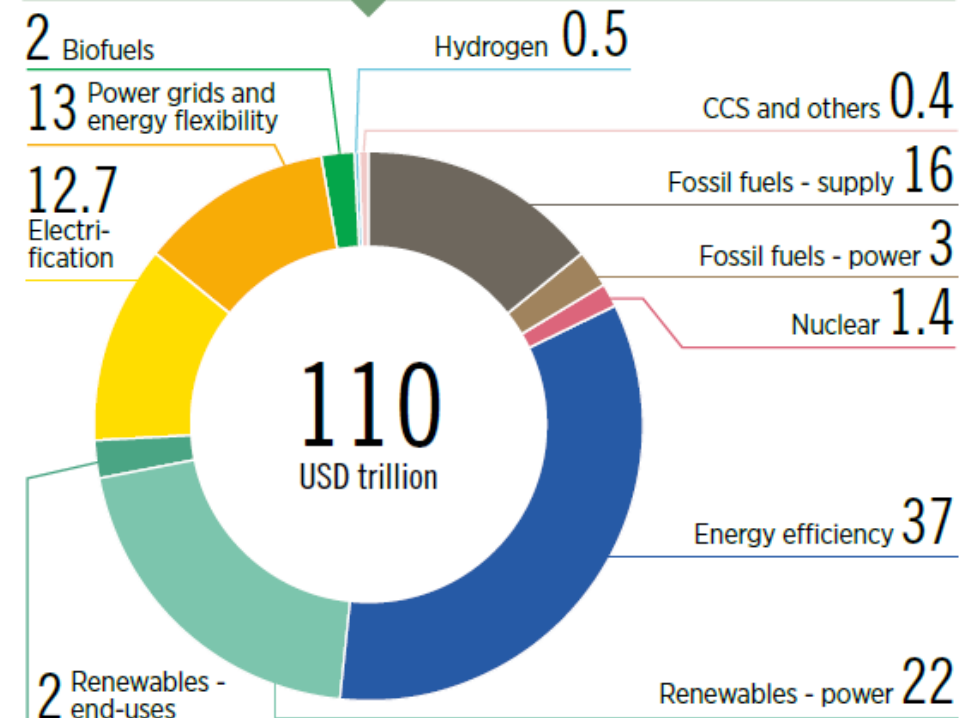
Notes: 1) TFEC – total final energy consumption; 2) Utility and distributed solar PV total additions (new as well as repowering); 3) Onshore and offshore wind total additions (new as well as repowering); 4) Passenger cars exclude 2/3 wheelers, buses and other electric mobility transport modes; 5) Heat pump estimates based on available data;

# Shifting investments to energy efficiency, renewables and the electrification of heat and transport

Reference Case investments between 2016-50 (USD trillion)

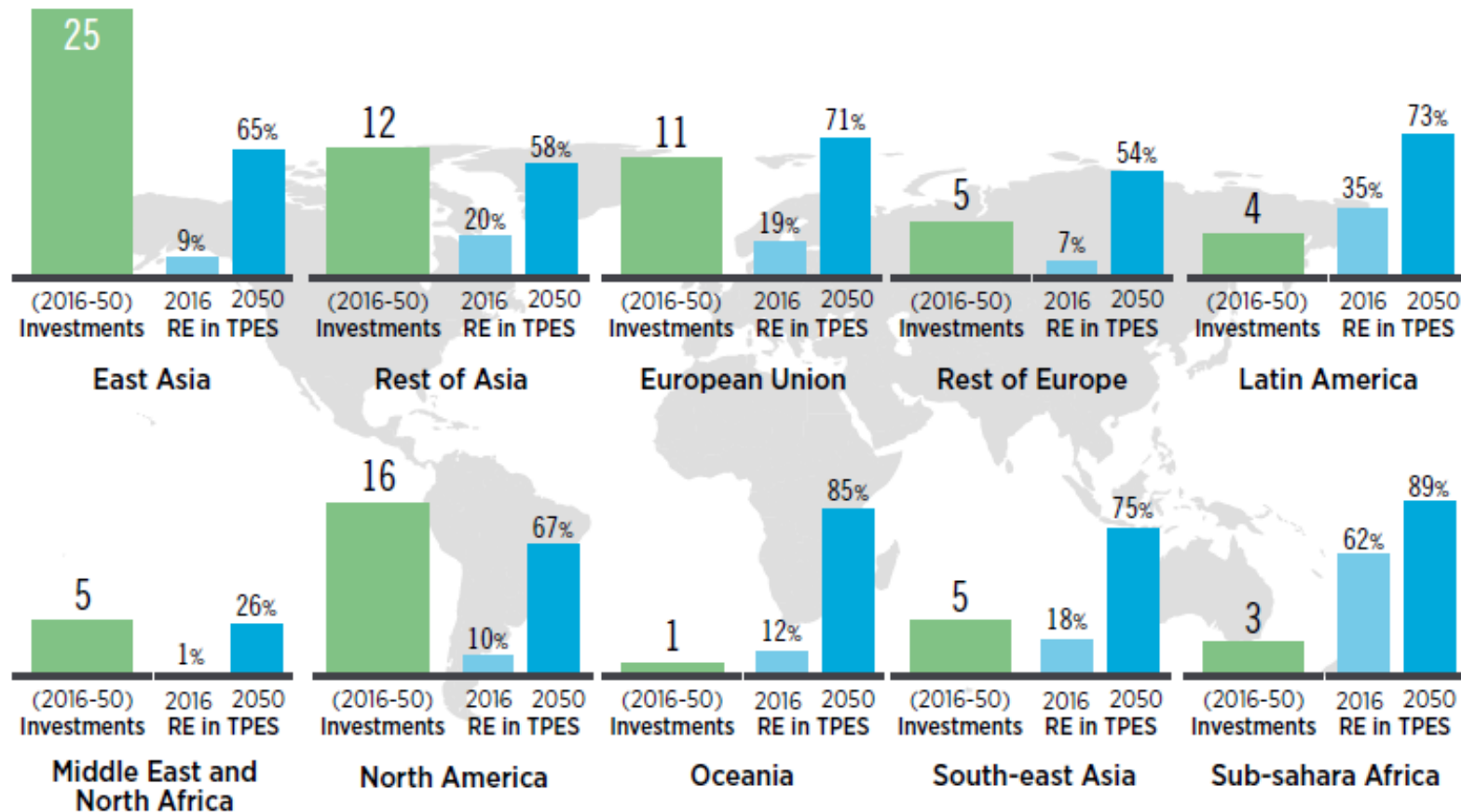


REmap Case investments between 2016-50 (USD trillion)



- The REmap Case increases investments in the global energy system by USD 15 trillion, and shifts investment into electrification, renewable energy and energy efficiency technologies, which together, would make up **four-fifths of the cumulative energy sector investments** over the period to 2050.

# Investments are widespread around the world

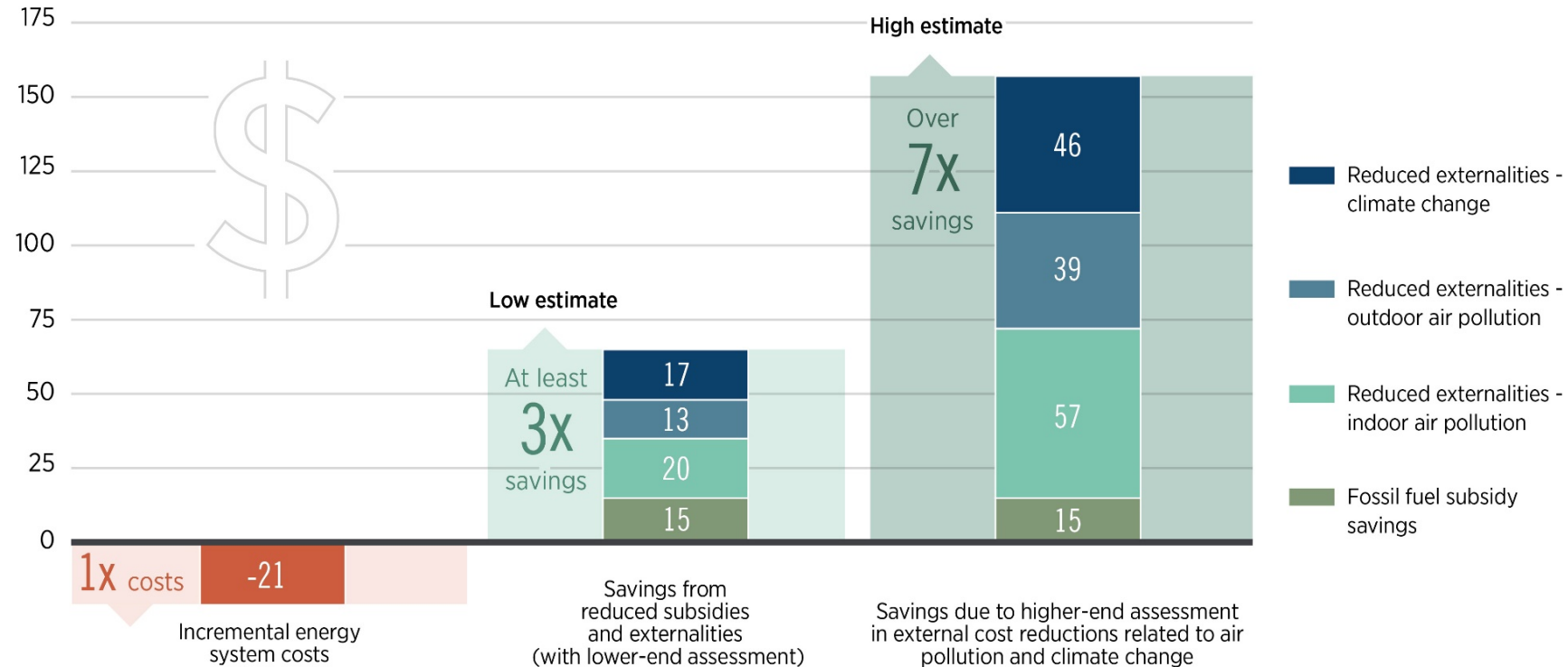


The **renewables share in the energy mix will need to increase in all regions up to 2050**. Sub-Saharan Africa (89%), Oceania (85%), South-East Asia (75%) and Latin-America (73%) and Europe (71%) will see the highest share. East Asia and North America will, however, require almost 50% of the total energy investment over the period in the REmap Case due to increasing energy demand.



# Investing in the energy transition is beneficial for society

Costs and savings for the period 2016-2050 for the REmap Case, compared to the Reference Case  
(USD trillion)

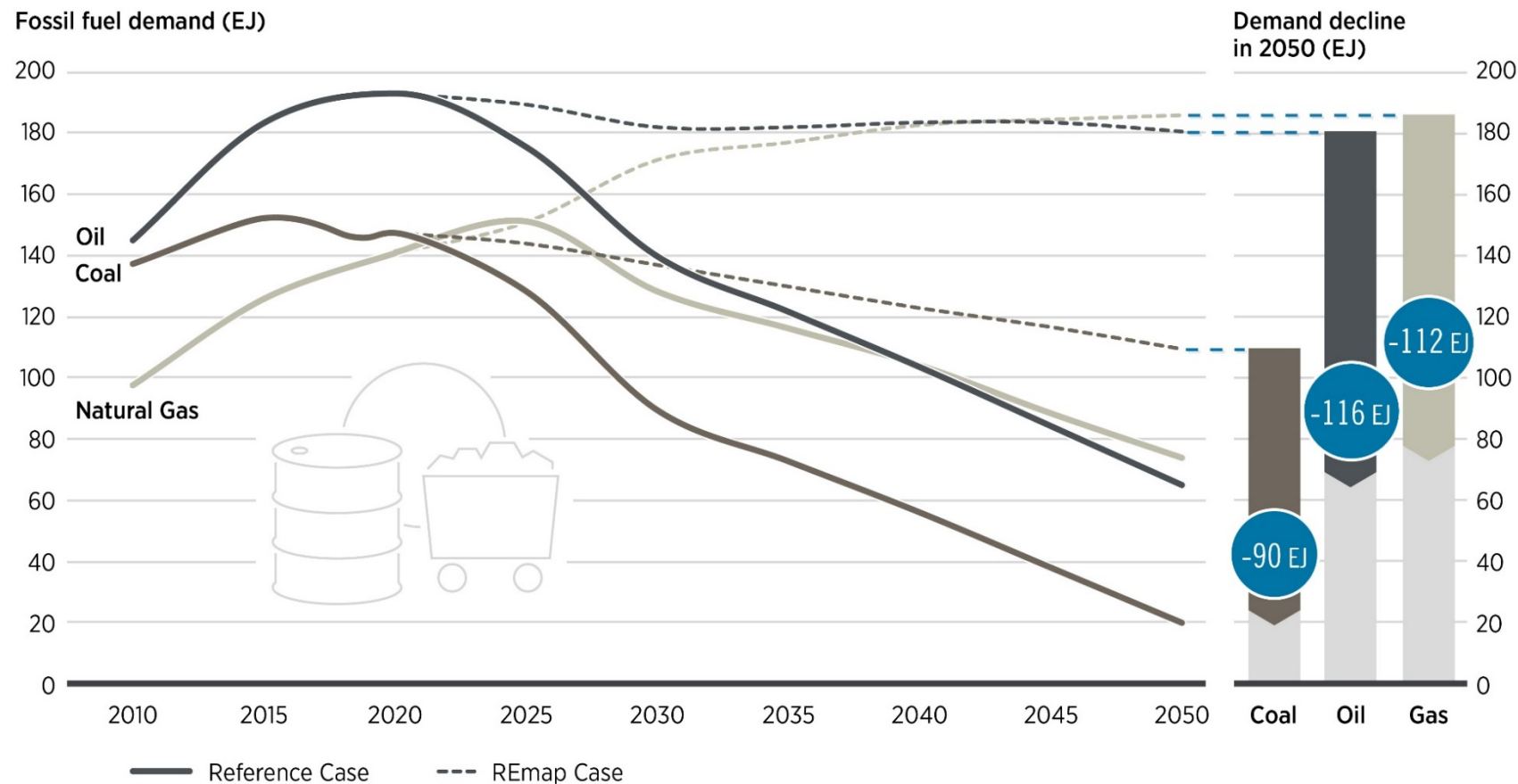


- For every dollar spent for the energy transition, **the payoff amounts to at least three dollars and, depending on how externalities are valued, up to seven dollars.**
- As renewables rise, net **energy subsidies fall**, as do health costs from air pollution and climate impacts. Half of the USD 21 trillion in additional expenditures, including investment and operational costs, could be covered by the savings on avoided subsidies



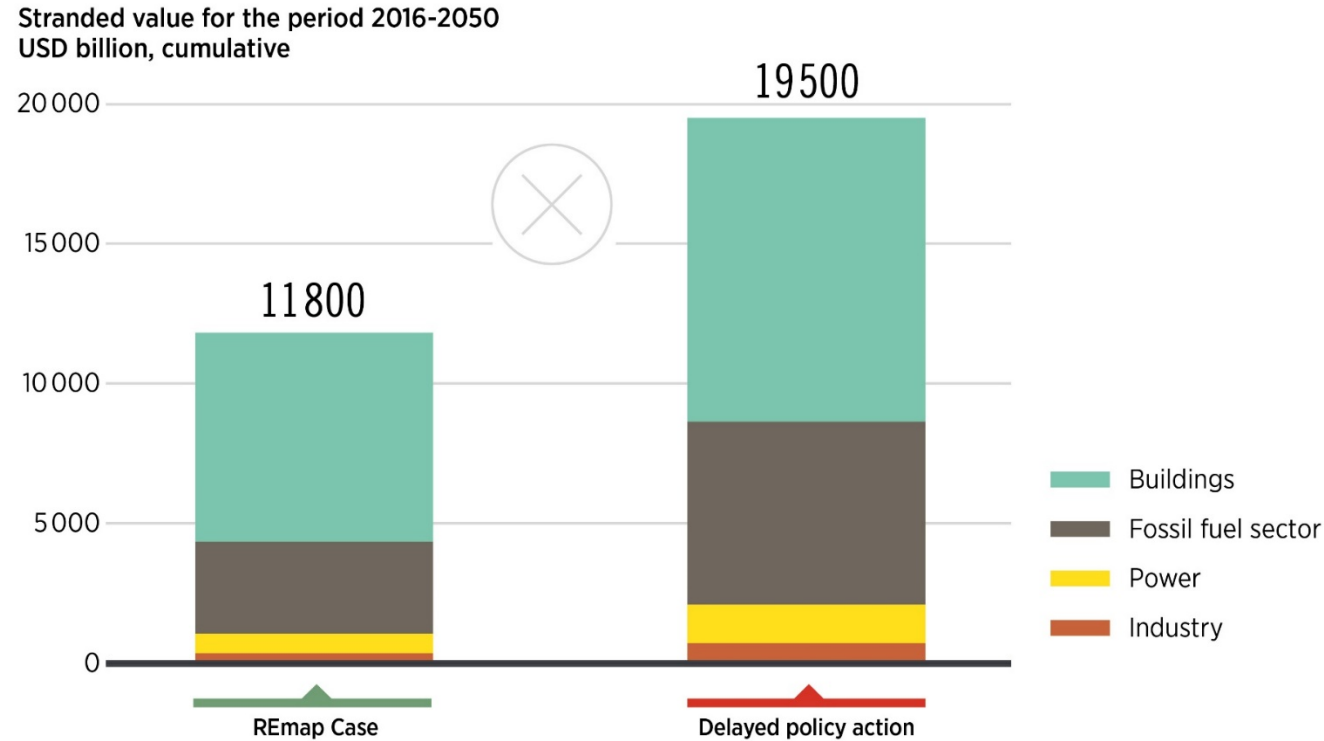
# Decline global demand for fossil fuels

Fossil fuel use (left, PJ/yr), 2015-2050; decline in fossil fuel usage by sector REmap Case relative to Reference Case (right, in 2050)



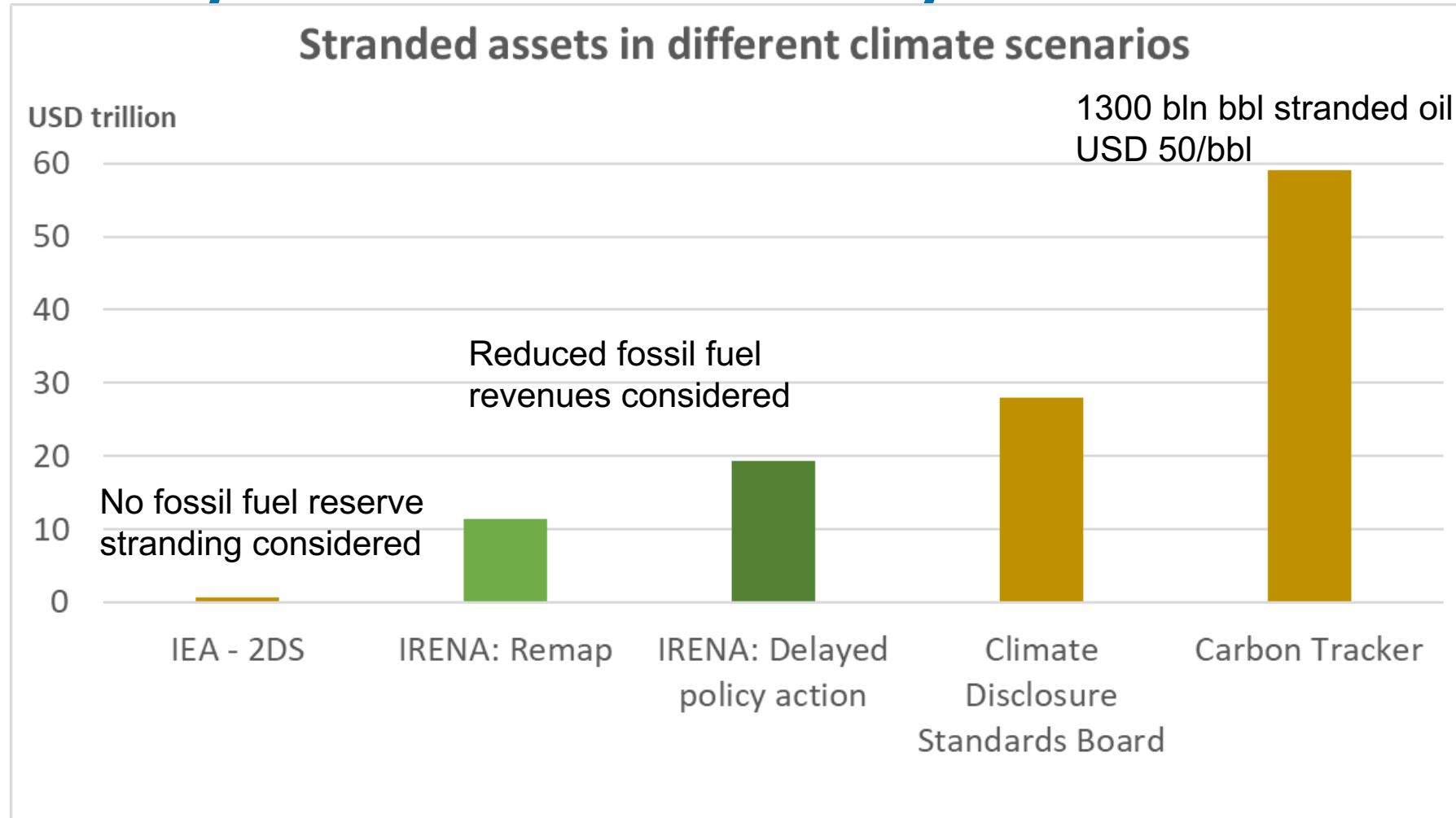
- With accelerated uptake of renewables, **both oil and coal demand decline significantly and continuously, with natural gas demand peaking around 2025**. Natural gas would be the largest source of fossil fuel in 2050.

# Stranded assets increase significantly if action to decarbonise the energy sector is delayed



- If Paris Agreement aims are met, the resulting stranded assets would amount to **almost USD 12 trillion by 2050**. This equals about one-third of additional investment needs or around 3% of today's global capital stock. **Delaying action, however, would increase those losses to as much as USD 20 trillion.**

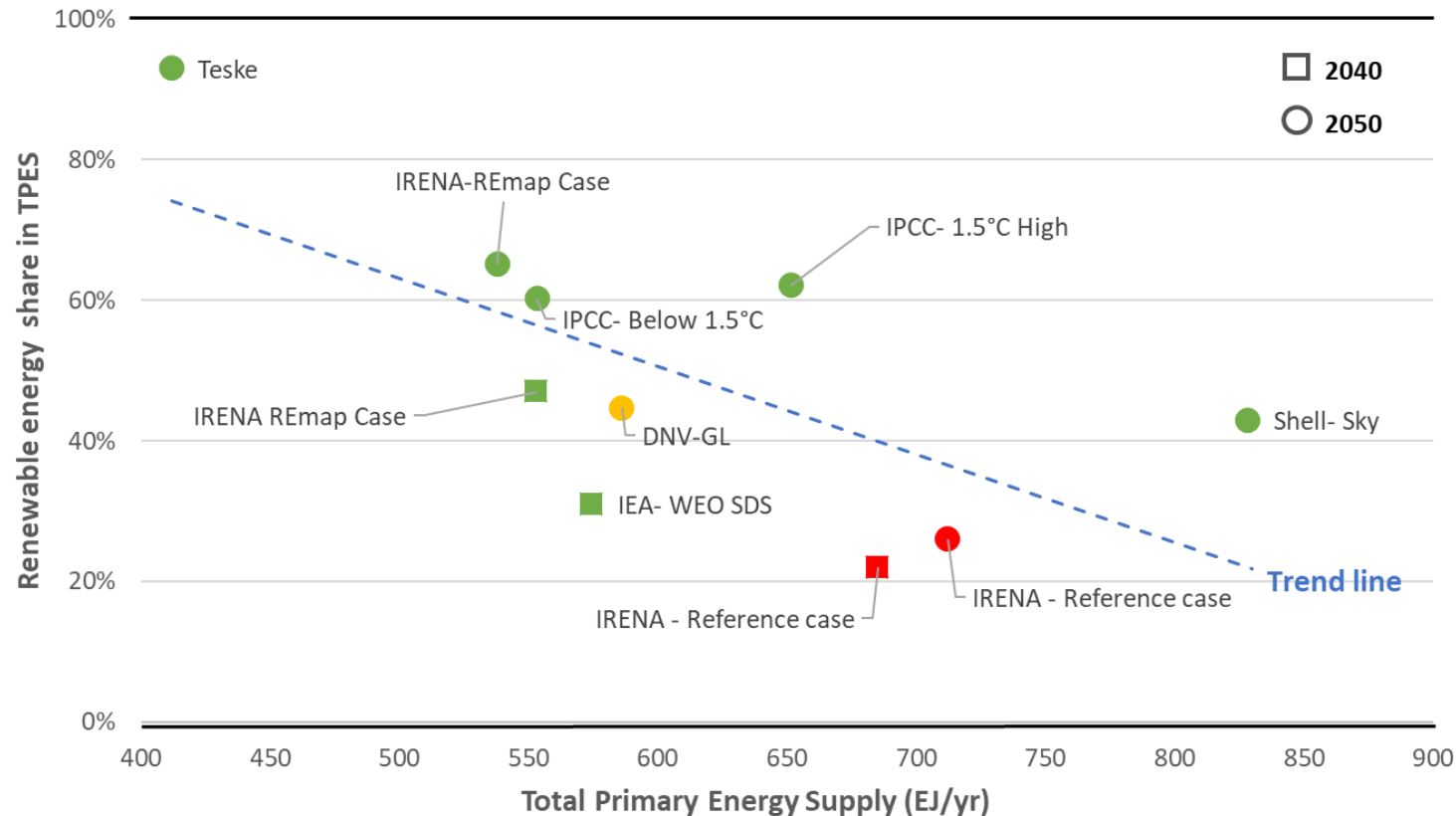
# Stranded assets estimates and definitions in different scenarios vary significantly because definitions vary



IRENA definition: Remaining book value of assets substituted or abandoned before the end of their anticipated technical lifetime and without recovery of any remaining value to stay within the carbon budget limit

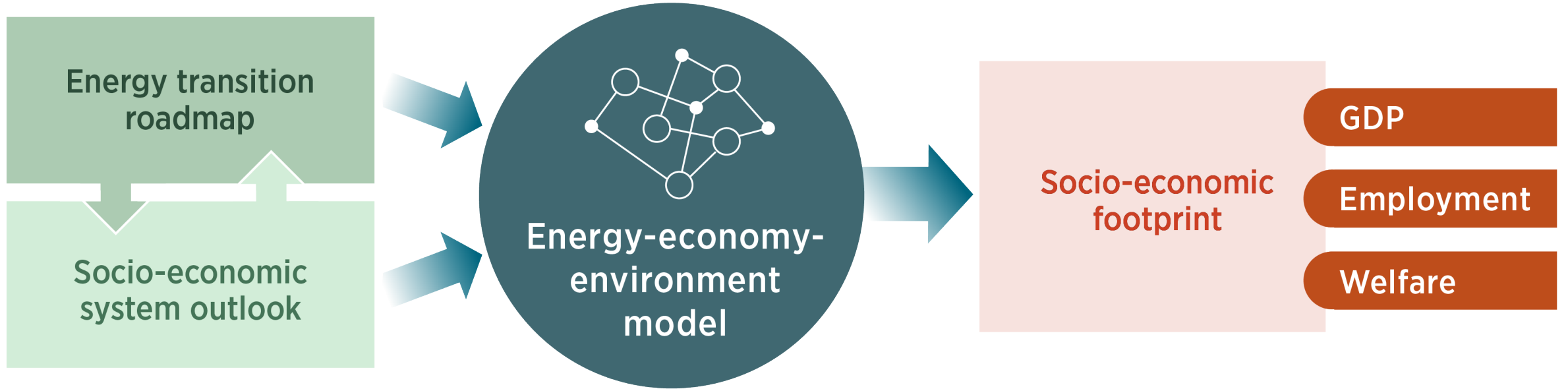
# There is a correlation between renewable energy share and energy demand

Renewable energy share and total primary energy projections in 2040 and 2050 in various climate scenarios



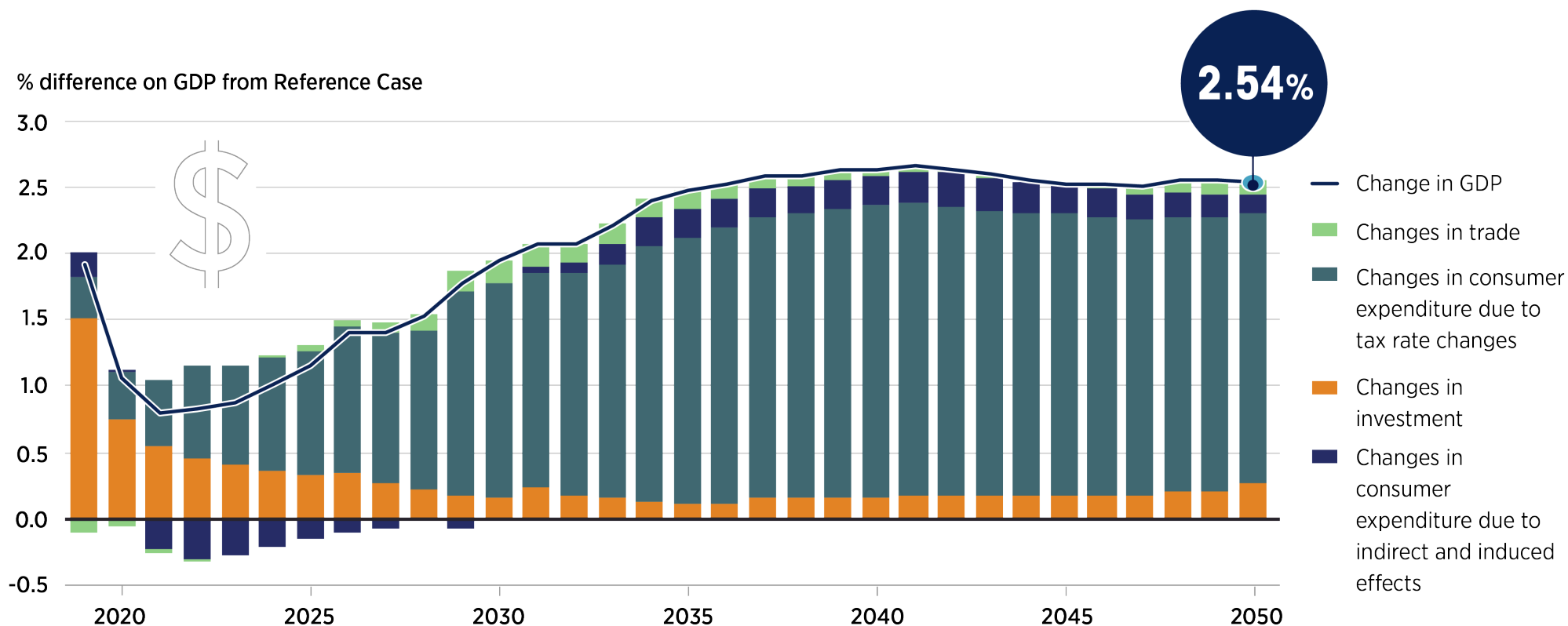
- Scenarios with higher renewable energy shares also have higher energy efficiency, **resulting in lower overall energy demand and emissions.**

# The socio-economic footprint of the energy transition



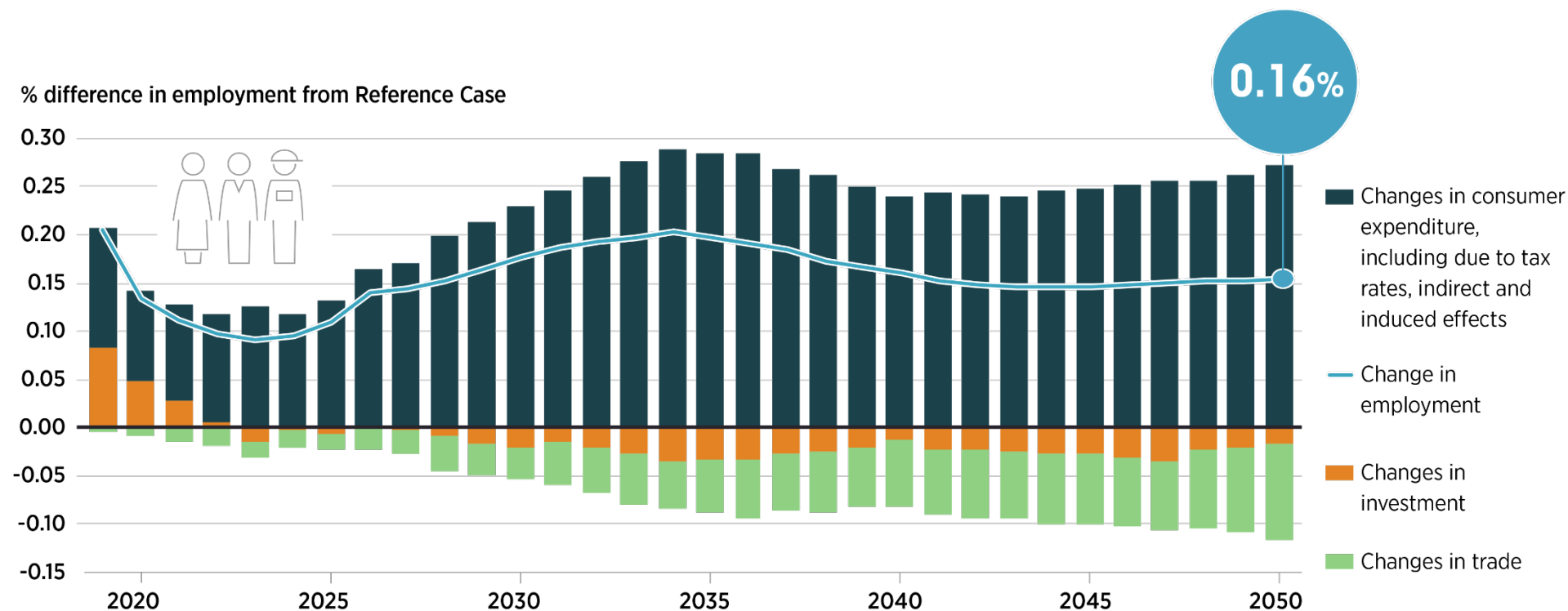
- **Both the energy and socio-economic systems will evolve during the transition**, with multiple feedback loops between them.
- **IRENA uses an integrated Energy-Economy- Environment model to evaluate the socio-economic footprint** that results from the interactions among different combinations of the energy transition roadmap and the socio-economic outlook.

# The energy transformation boosts global GDP



- To gain insight about the structural elements underpinning the evolution of GDP as a consequence of the interactions between the energy transition and the socio-economic system, the macroeconomic modelling undertaken by IRENA disaggregates the **evolution of GDP into four main drivers: Trade, consumer expenditure due to tax rate changes, consumer expenditure due to indirect and induced effects and investment.**

# Economy-wide employment witnesses growth

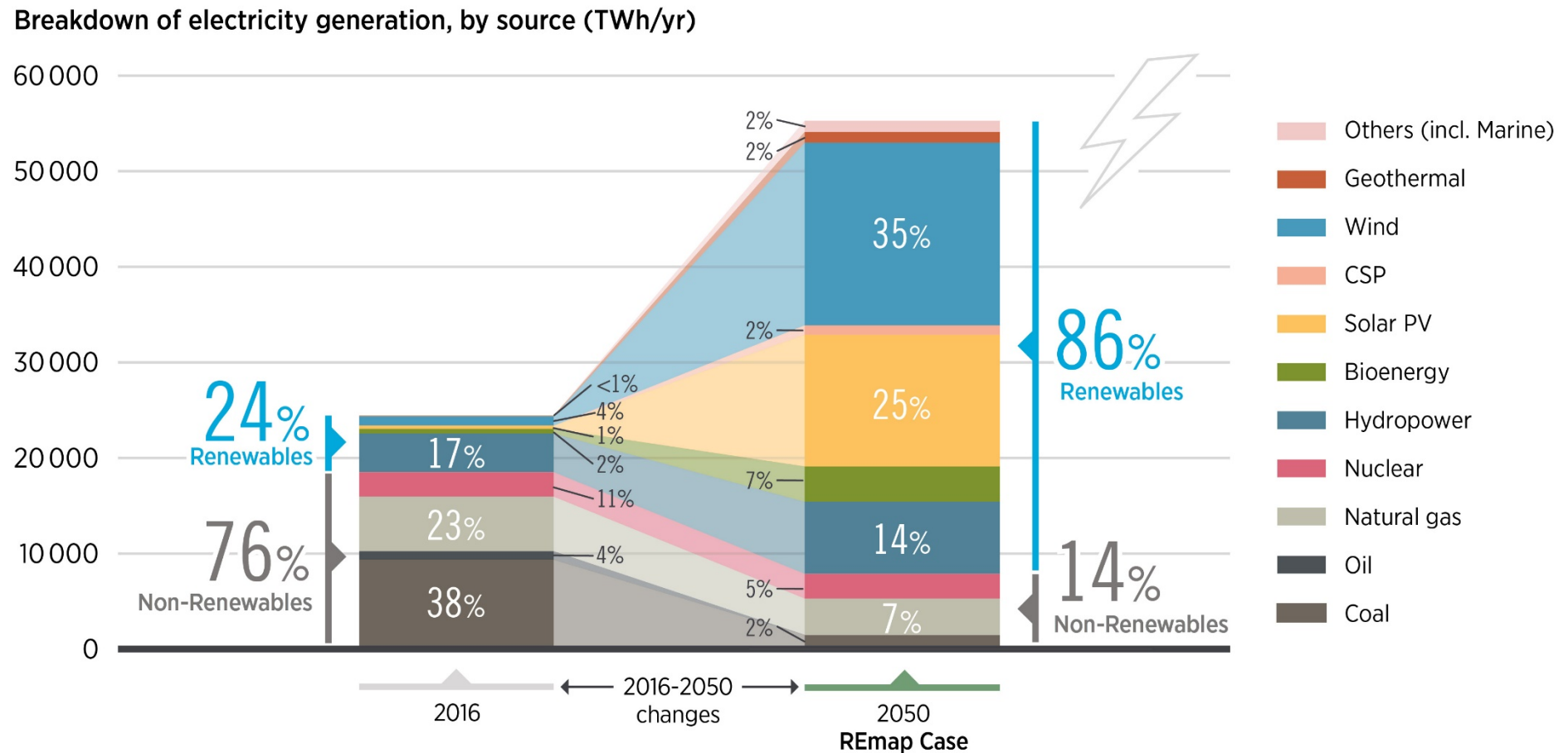


- **Global employment increases by 0.2% (7 million jobs).**
- To gain insight about the structural elements underpinning the evolution of Employment as a consequence of the interactions between the energy transition and the socio-economic system, **the macroeconomic modelling undertaken by IRENA disaggregates the evolution of Employment into three main drivers: Trade, consumer expenditure (including tax rates and indirect and induced effects) and investment.**

# Sector views



# The rising importance of solar and wind energy in the power sector



- Gross power generation would almost double, with 86% coming from renewables.

# Power sector key indicators infographic



2016

REmap Case 2050

## RENEWABLE ENERGY AND ELECTRIFICATION SHARES



Renewable share in the total electricity generation

24%

86%



Electricity demand

24 330 TWh/yr

55 188 TWh/yr

## INSTALLED POWER GENERATION CAPACITY

HYDROPOWER

Hydropower



1 287 GW

of which pumped hydro 155 GW



2 147 GW

325 GW

WIND

Wind power



474 GW

Onshore / Offshore

459 / 14 GW



6 044 GW



5 044 / 999 GW

SOLAR

Solar PV



297 GW

CSP

5 GW



8 519 GW



309 GW

BIOENERGY



100 GW



685 GW

GEO THERMAL

Heat



12 GW



162 GW

Others (incl. marine, hybrid)

<1 GW



511 GW

OTHERS

## ENERGY-RELATED CO<sub>2</sub> EMISSIONS

Energy related CO<sub>2</sub> emissions

11.3 Gt CO<sub>2</sub>/yr

2.3 Gt CO<sub>2</sub>/yr

Avoided CO<sub>2</sub> emissions in 2050 compared to Reference Case: 8.2 Gt CO<sub>2</sub>/yr

## INVESTMENT

Total investments for the period 2016-2050



Power generation (fossil)

4 USD trillion

Power generation (renewable)

22 USD trillion

Power system flexibility and grids

13 USD trillion

## STRANDED ASSETS

Total stranded assets between 2016-2050

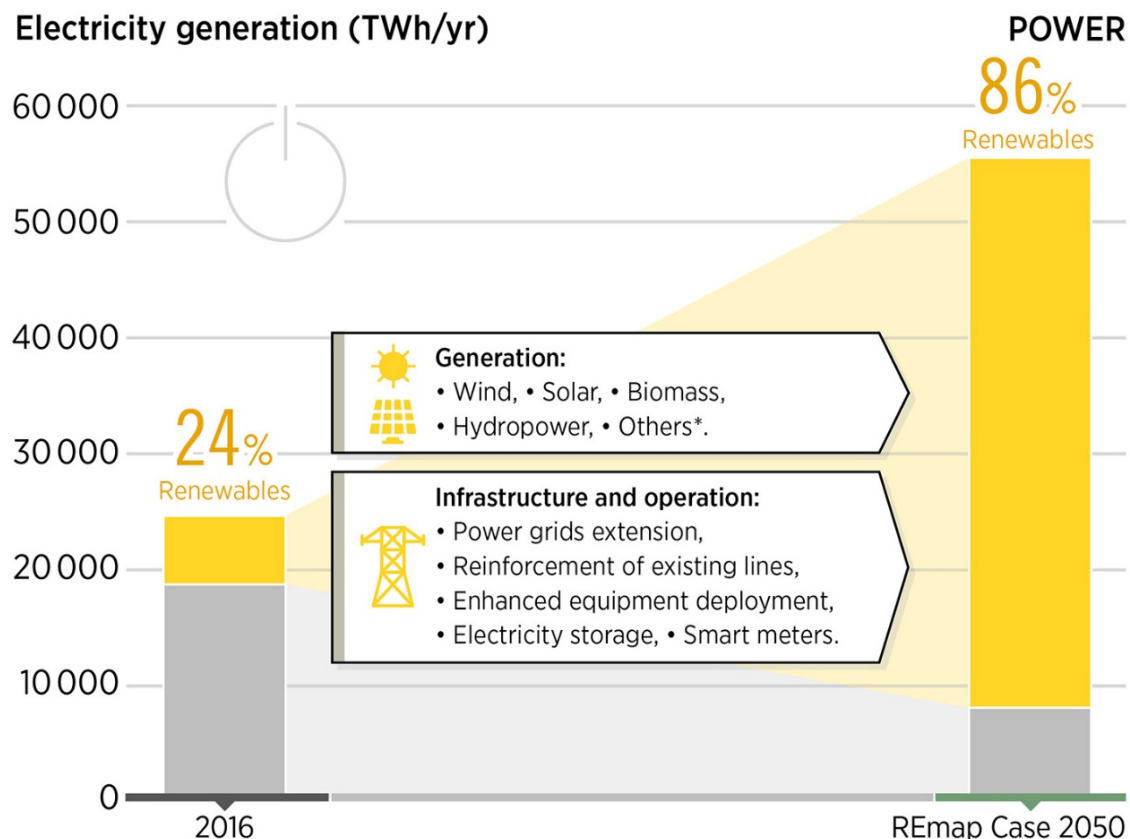
Delayed Policy Action

1.4 USD trillion

REmap Case 2050

0.7 USD trillion

# Actions needed now - Power



## ACCELERATE RENEWABLES CAPACITY ADDITIONS:

- Identify and map renewable energy resources and develop a portfolio of financeable projects.
- Construct no new coal power plants and plan and implement the phase-out of coal capacities approaching end of its lifetime.

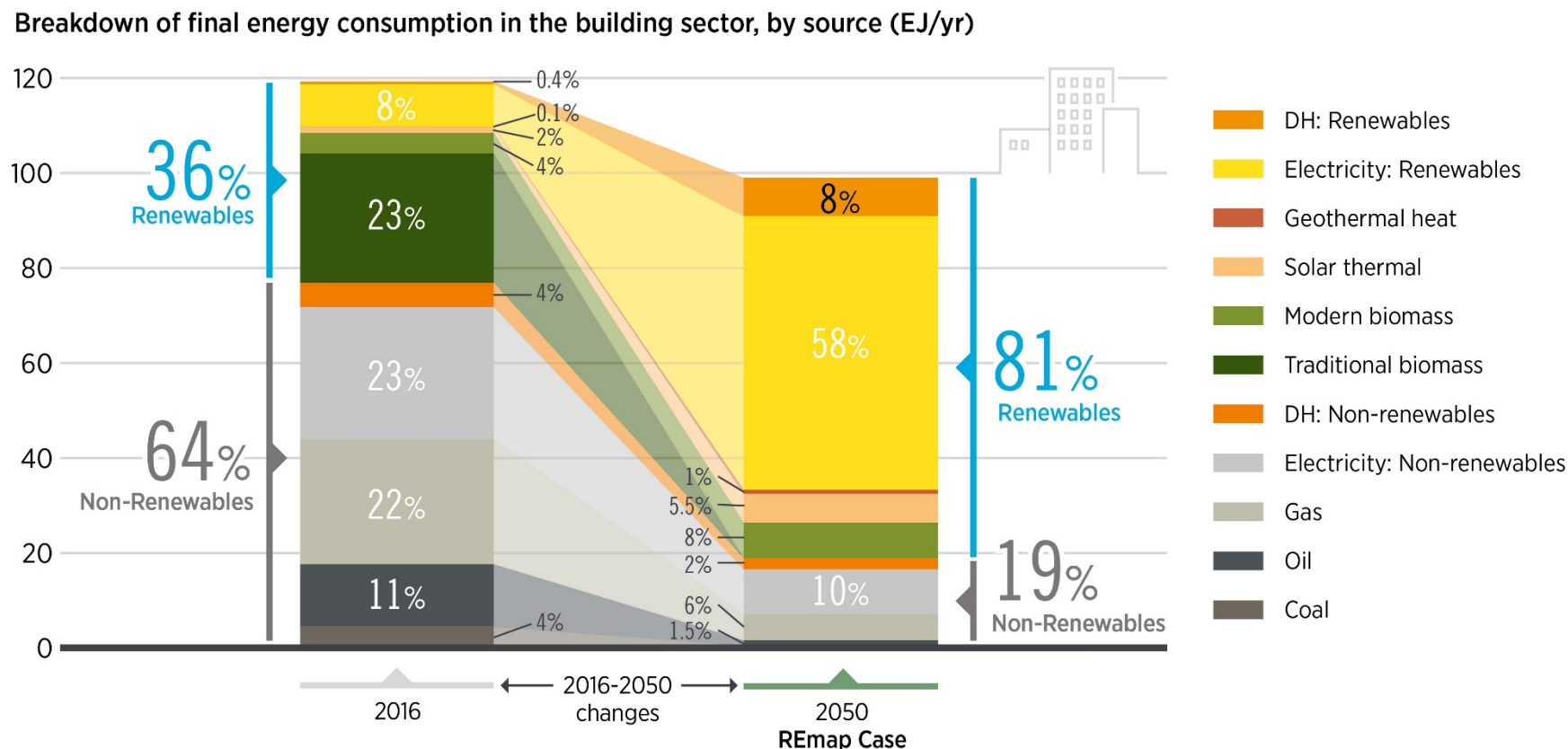
## PLAN FOR THE POWER SECTOR TO ACCOMMODATE INCREASING SHARES OF VARIABLE RENEWABLE ENERGY:

- Prioritize to improve flexibility of power system (with flexible supply, storage, demand response, power-to-X, electric vehicles, digital and information and communication technologies, etc.). Update grid codes.
- Deploy microgrids to improve resilience of the grid and energy access rate with renewable sources. Deploy super grids to strengthen the interconnections among countries within a region.
- Deploy cost-reflective tariff structures by properly readjusting the balance between volumetric charges (USD/kWh), fixed charges (e.g., USD/meter-month) and, where applicable, demand charges (USD/kW).

## SUPPORT THE DEPLOYMENT OF DISTRIBUTED ENERGY RESOURCES:

- Incentivise energy consumers to become prosumers.
- Support regulatory and pricing policies including the right to generate and sell electricity, tariff regulation and grid-arrival policies.
- Enable energy aggregators to foster the deployment of distributed energy resources.

# The increasing use of renewable electricity in buildings



- Renewable electricity would reach a 58% share in the buildings sector by 2050.
- Together with modern biomass, solar thermal and district heating, overall renewables could ramp up to 81%, from 36% today.

# Buildings sector key indicators infographic



## BUILDINGS

2016

REmap Case 2050

### RENEWABLE ENERGY AND ELECTRIFICATION



Renewable share in final energy use in buildings

36%

81%



Electricity share in final energy use in buildings

31%

68%

### RENEWABLE ENERGY INDICATORS



#### BIOMASS

Traditional cookstoves

568 million units

0

Modern cookstoves

48 million units

593 million units

Modern biomass heat

4.3 EJ/yr

7.5 EJ/yr



#### SOLAR THERMAL

Solar thermal collector area

622 million m<sup>2</sup>

4 386 mil. m<sup>2</sup>



#### GEOTHERMAL

Geothermal heat

0.30 EJ/yr

1.3 EJ/yr



#### HEAT PUMPS

Heat pumps

20 million units

253 mil. units

### ENERGY RELATED CO<sub>2</sub> EMISSIONS

2.9 Gt CO<sub>2</sub>/yr

0.4 Gt CO<sub>2</sub>/yr

Avoided CO<sub>2</sub> emissions in 2050 compared to Reference Case: 2.2 Gt CO<sub>2</sub>/yr

### INVESTMENT

Total investments for decarbonisation over the period 2016-2050

REmap Case 2050

32

USD trillion



### STRANDED ASSETS

Total stranded assets between 2016 and 2050

Delayed Policy Action

10.9 USD trillion

REmap Case 2050

7.5 USD trillion

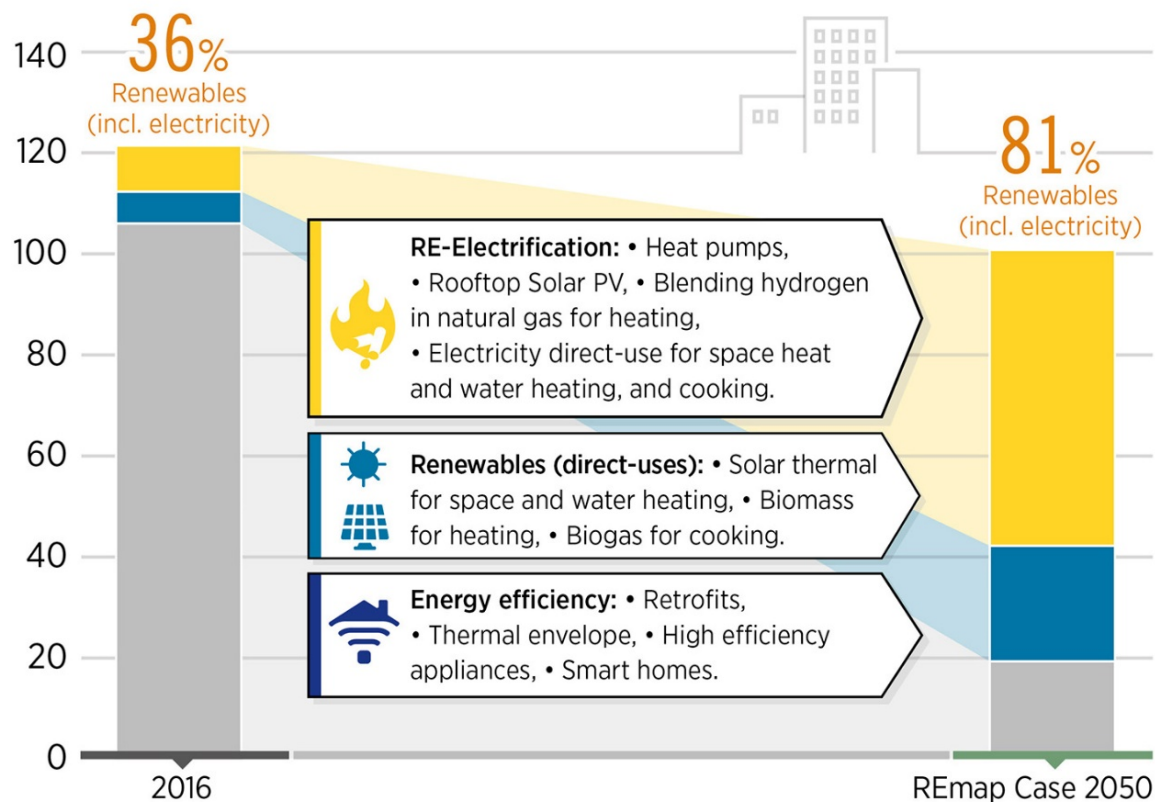


# Actions needed now - Buildings



Final energy consumption (EJ/yr)

BUILDINGS



## REDUCE ENERGY CONSUMPTION IN BUILDINGS:

- Establish and improve energy efficiency building codes and standards (incl. appliances (eg. air conditioners), lighting (eg. LED lights) and equipment (eg. efficient boilers)).
- Adopt programmes for retrofitting/renovation including financing schemes.
- Align renewable heat and energy efficiency policies to leverage synergies and to accelerate the pace of energy efficiency improvements.

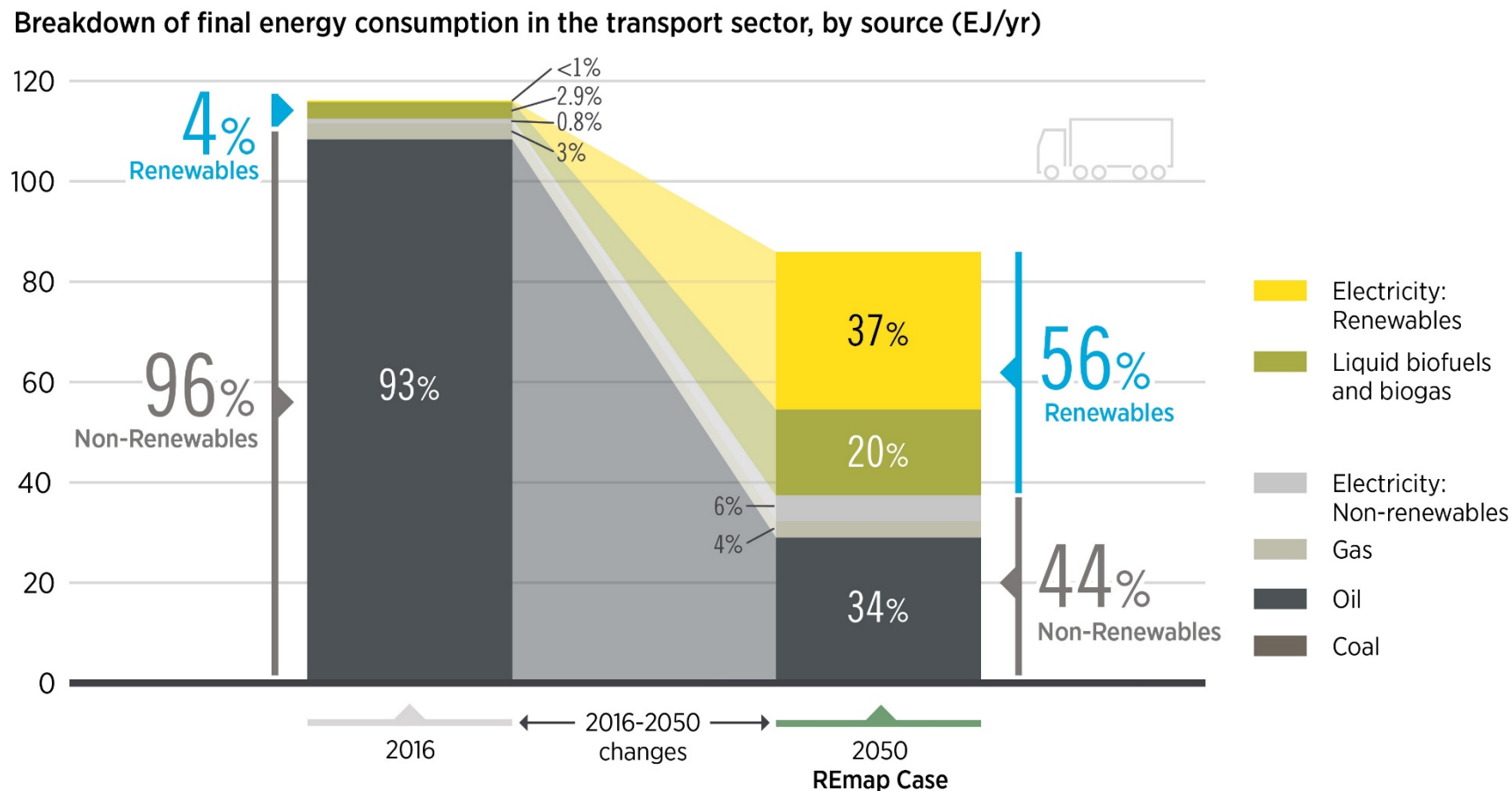
## SUPPORT AND FOSTER THE DEPLOYMENT OF DISTRIBUTED ENERGY RESOURCES:

- Remove regulatory barriers for prosumers that restrict them from taking an active role in the energy system transformation. Capitalise on smart-homes and digitalisation to allow demand management.
- Promote community ownership models and innovative financing schemes.
- Accelerate rollout of smart meters.

## SCALEUP RENEWABLE SHARE UPTAKE IN THE BUILDINGS SECTOR:

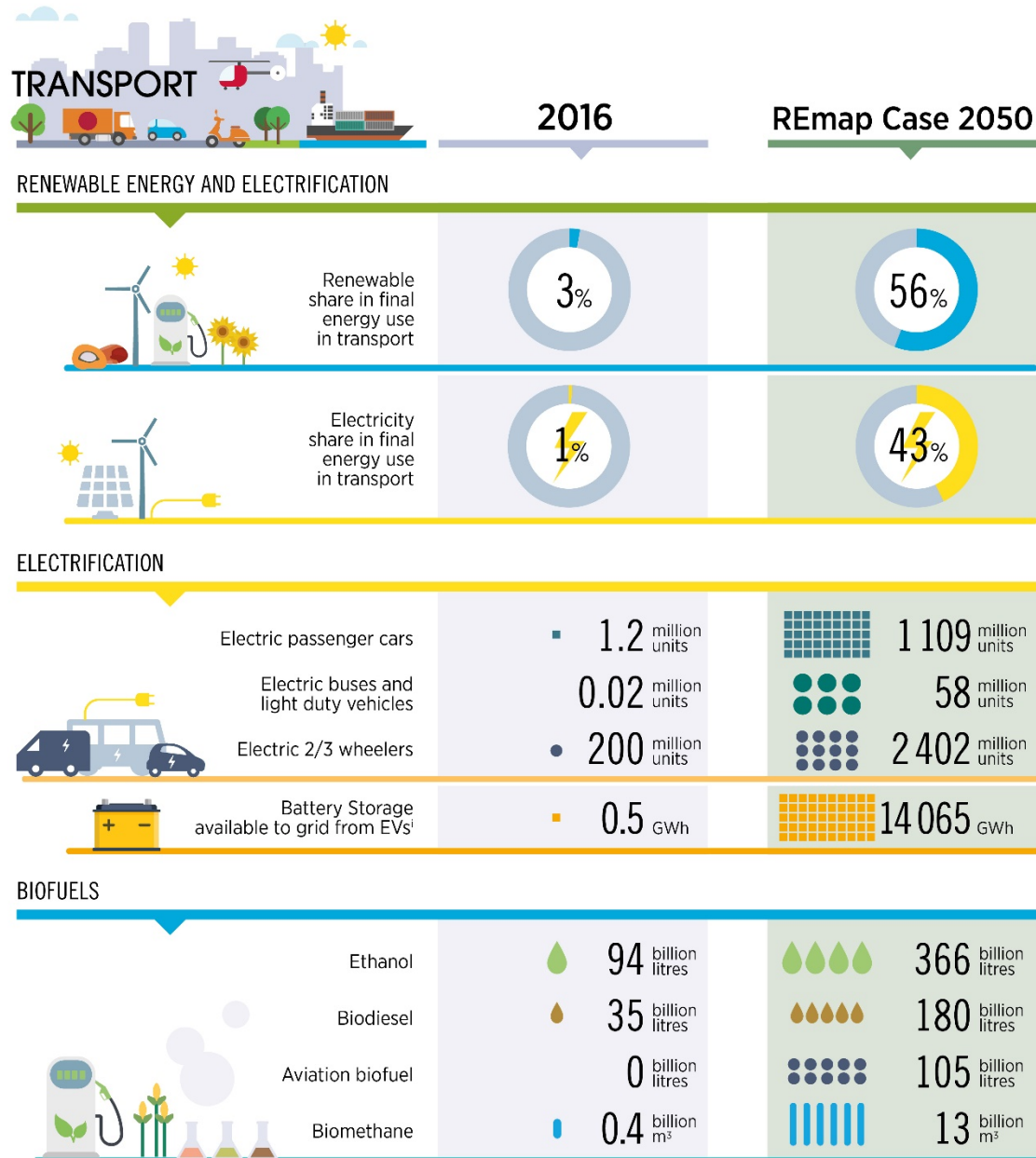
- Promote low-carbon heating technologies: heat pumps, solar heating, modern bioenergy for heating ). Apply these renewable technologies for district heating.
- Establish a long term strategy for heat decarbonisation.
- Incentivise renewable based cooling solutions.
- Phase out traditional biomass as cooking fuel and replace with clean and efficient cookstoves (biogas, modern solid biomass and electricity).

# Increasing electrification in the transport sector



- Renewable electricity use could increase significantly in the transport sector by 2050, providing 37% of total transport energy consumption and, due to higher efficiency, covering 60% of the overall transport activity.

# Transport sector key indicators infographic



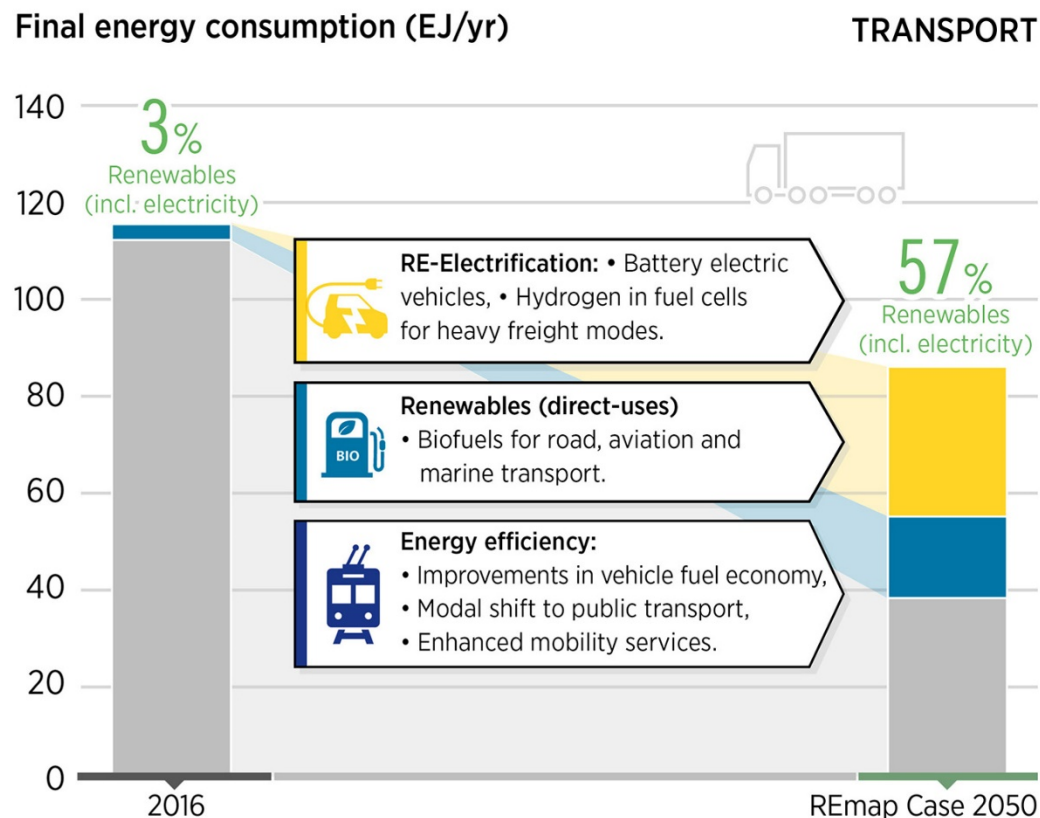
## ENERGY RELATED CO<sub>2</sub> EMISSIONS



<sup>i</sup> Considering 50% grid connected Electric passenger cars and 25% grid connected electric 2/3 wheelers by 2050



# Actions needed now - Transport



## REDUCE THE ENERGY NEED FOR TRANSPORT:

- Deploy advanced digital communication technologies to reduce the transport needs (eg. teleconferencing over traveling) and to improve efficiency of transport by better utilizing the assets (eg. re-routing due to traffic).
- Promote mobility services: Promote vehicle sharing and autonomous driving.
- Accelerate modal shift from passenger cars to public transport (electric railways or trams or electric buses).

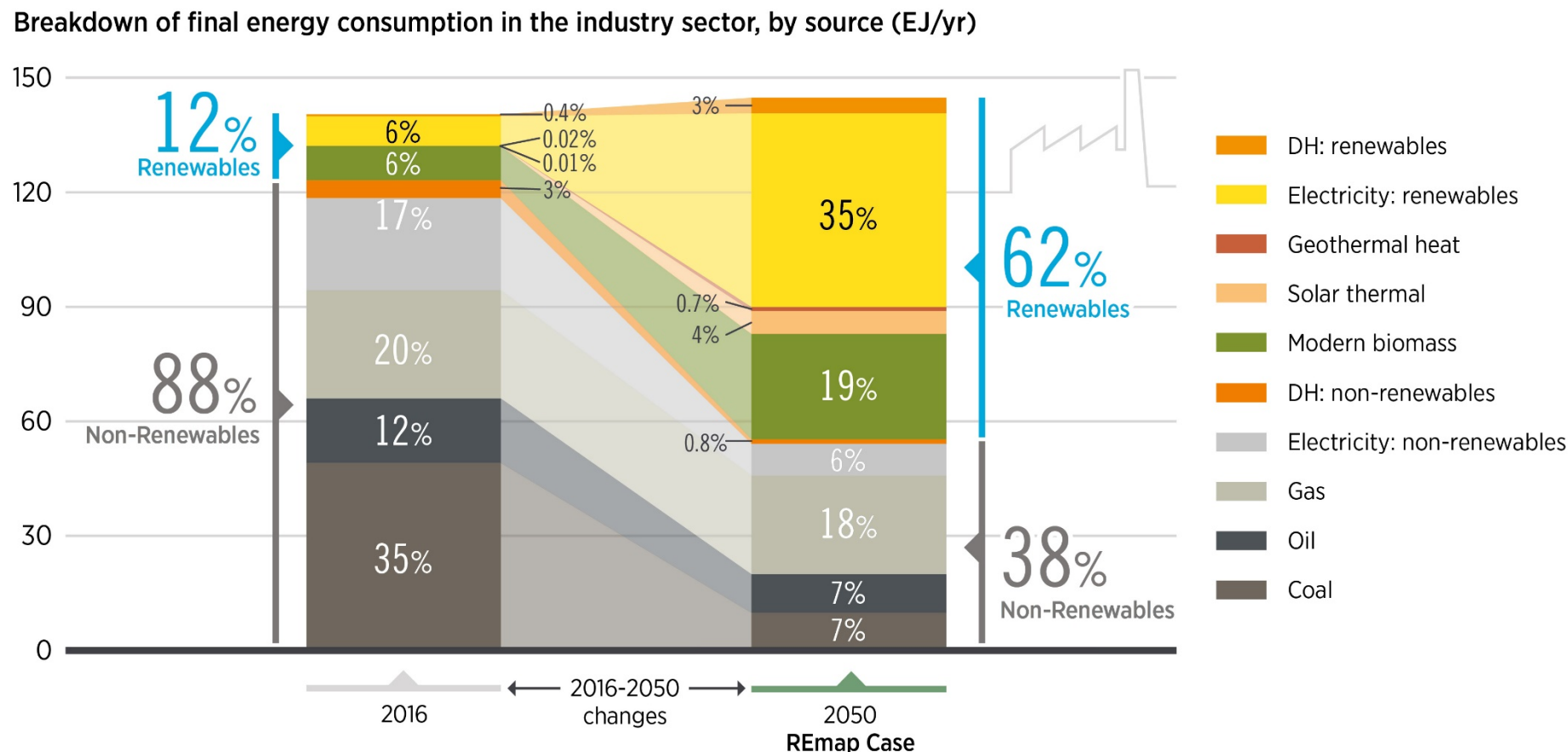
## ACCELERATE THE UPTAKE OF ELECTRIC MOBILITY:

- Establish minimum standards for vehicle emissions. Give the priority for electric vehicles for city access.
- Incentivise charging infrastructure rollout.
- Strengthen link between the power and transport sectors for integrated planning and policy designs (vehicle-to-grid services).
- Deploy low-emissions city trucks.

## FOSTER BIOFUELS IN ROAD, AVIATION AND SHIPPING:

- Eliminate fossil fuel subsidies and implement carbon pricing to increase the competitiveness of renewable fuels in the shipping and aviation.
- Adopt supporting policies to scale up sustainable production of first- and second-generation biofuels. Introduce specific mandates for advanced biofuels and put in place direct financial incentives along with financial de-risking measures.

# Renewable electrification and bioenergy taking the lead in the industry sector



- By 2050 the share of renewables in the industrial sector needs to grow by more than 5 times. Renewable electrification would make up around 1/3 of the sector's energy demand, followed by biomass providing 1/5.

# Industry sector key indicators infographic



## INDUSTRY

2016

REmap Case 2050

### RENEWABLE ENERGY AND ELECTRIFICATION



Renewable share in final energy use in sector consumption

12%

62%



Electricity share in the total sector consumption

25%

42%

### RENEWABLE ENERGY AND ELECTRIFICATION INDICATORS



#### BIOMASS

Biomass heat (incl. CHP)



8 EJ/yr



27 EJ/yr

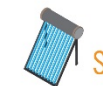
Biomass feedstock



0.8 EJ/yr



11 EJ/yr



#### SOLAR THERMAL

Concentrated solar thermal



0.1 GWth



27 GWth

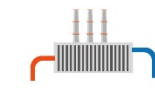
Solar thermal collector area



1 million m<sup>2</sup>



11 million m<sup>2</sup>



#### GEOTHERMAL

Heat



0.02 EJ/yr



1.2 EJ/yr



#### HEAT PUMPS

Heat pumps



0.2 million units



80 mil. units

### ENERGY RELATED CO<sub>2</sub> EMISSIONS

Energy related CO<sub>2</sub> emissions

7.6 Gt CO<sub>2</sub>/yr

Process emissions (including CCS)

2.9 Gt CO<sub>2</sub>/yr

3.2 Gt CO<sub>2</sub>/yr

Avoided CO<sub>2</sub> emissions in 2050 compared to Reference Case: 4.9 Gt CO<sub>2</sub>/yr

0.9 Gt CO<sub>2</sub>/yr

### INVESTMENT

Total investments for decarbonisation over the period 2016-2050

REmap Case 2050

6.08 USD trillion



### STRANDED ASSETS

Total stranded assets between 2016 and 2050

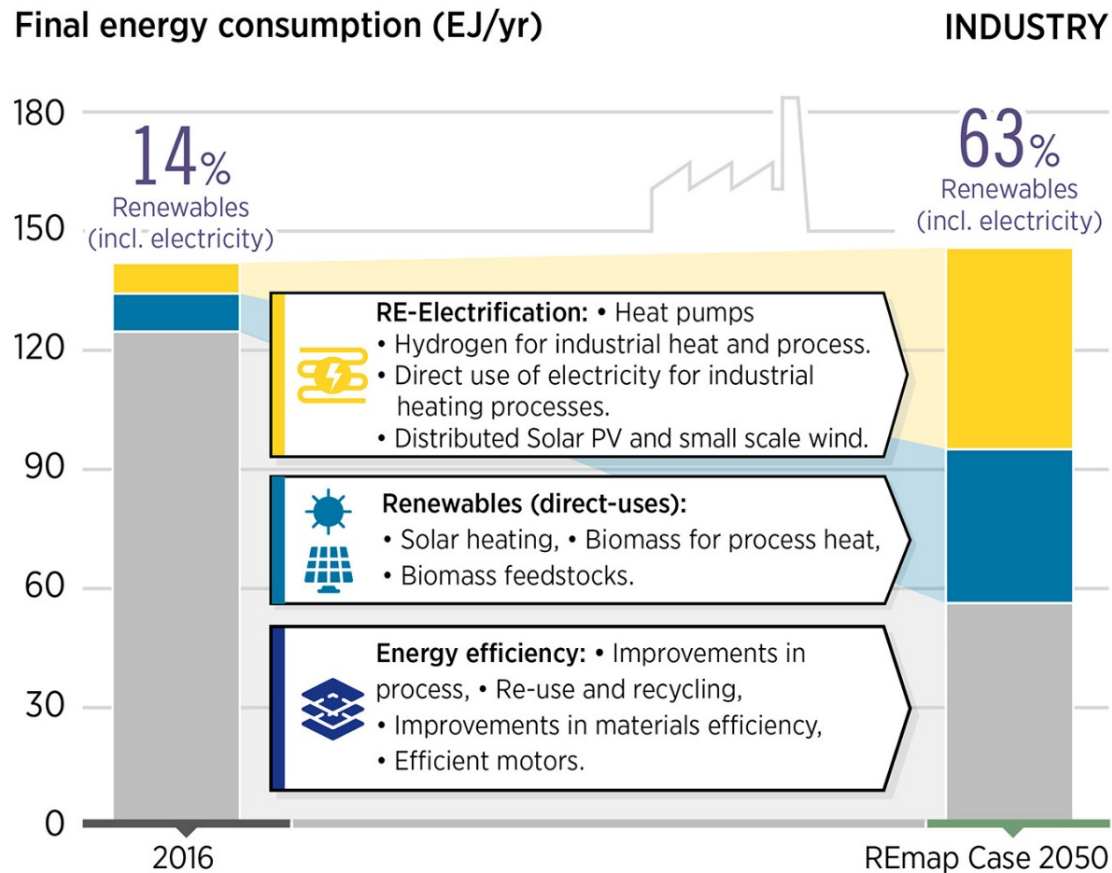
Delayed Policy Action

0.72 USD trillion

REmap Case 2050

0.36 USD trillion

# Actions needed now - Industry



## REDUCE ENERGY CONSUMPTION IN INDUSTRIES:

- Promote actions towards circular economy (material recycling, waste management, improvements in materials efficiency and structural changes such as reusing and recycling).
- Incentivise and adopt best available technologies (BAT) and efficiency standards.

## ENABLE CORPORATE SOURCING OF RENEWABLES:

- Support a credible and transparent system for certification and tracking of renewable energy attributes.
- Consider an energy market structure that allows for direct trade between companies of all sizes and renewable energy developers – such as through PPAs.
- Work with utilities or electric suppliers to provide green corporate procurement options.
- Empower companies to engage in direct investment for self-generation.

## ACCELERATE THE DEPLOYMENT OF LOW-CARBON TECHNOLOGIES IN INDUSTRIAL PROCESS HEATING:

- Remove existing barriers and incentivise low-carbon heating technologies deployment: Solar thermal heating/modern bioenergy and heat pumps.
- Support emerging technologies in biomass and hydrogen. Use renewable-produced hydrogen to replace fossil fuel-based feedstocks and process heat (e.g., iron and steel sub-sectors, ammonia production).
- Implement appropriate carbon pricing in line with the real costs of the externalities and the elimination of existing subsidies for carbon-intensive fuels (where those still exist).

# Conclusion



# Key actions needed



- The power sector needs to be transformed to accommodate growing shares of variable renewables.



- Accelerating the electrification of the transport and heating sectors is crucial for the next stage of energy transformation.



- Hydrogen produced from renewable electricity could help to reduce fossil-fuel reliance.



- Decarbonising the global energy system requires swift and decisive policy action

- *With best of available technologies, policies should create right conditions to accelerate clean energy investments.*
- *Foster innovations and technology advancements.*
- *Need for better alignment and co-ordination between energy and climate policies (SDGs, NDCs).*
- *Close co-operation between the public and private sectors will be key.*



# Continued reports and activities for Global Energy Transformation Roadmap

## Available online

### Global energy transformation: The REmap transition pathway (+background report)

- Status of the energy transition
- Perspective for the global energy system to 2050 based on current and planned policies (the Reference Case).
- Detailed REmap transition pathway to 2050 – an energy pathway aligned with the well-below 2°C target of the Paris climate goals.



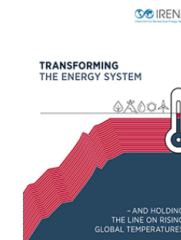
### Wind roadmap to 2050

- Technology deployment pathway.
- Annual and cumulative investments.
- Cost reductions and improvements in capacity factor.
- Innovations and technology advancements.
- Employment, supply chain and market expansion
- Emissions reduction potential.



### \$ Clean energy investments

- Pathway for the global energy transformation by 2050.
- Investment needs to achieve Paris Climate goals – sectors and regions.
- Socio-economic footprint of the energy transformation.
- Drivers and barriers to meet the clean energy investments.
- Input for UN Climate summit in September 2019.



## Forthcoming in Nov 2019



### Solar PV roadmap to 2050

- Technology deployment pathway.
- Annual and cumulative investments.
- Cost reductions and improvements in efficiency of modules.
- Innovations and technology advancements.
- Business models.
- Employment.
- Supply chain and market expansion.
- Emissions reduction potential.

**Thank you!**

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