Ch 4. Global Energy Transformation. A road map to 2050

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Chapter outline

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Preliminary notes

This chapter is based on the report entitled "Global Energy Transformation. A road map to 2050" (IREMA, 2019b). The report focuses its analysis on **two pathways** for the global energy system:

- **Reference Case:** This scenario considers current and planned policies of countries. It includes commitments made in Nationally Determined Contributions and other planned targets. It presents a perspective based on governments' current projections and energy plans.
- **REmap Case:** This scenario includes the deployment of low-carbon technologies, based largely on renewable energy and energy efficiency, to generate a transformation of the global energy system that limits the rise in global temperature to well below 2 degrees Celsius above pre-industrial levels. The scenario is focused on energy-related carbon dioxide emissions, which make up around two-thirds of global greenhouse gas emissions.

Preliminary notes

The **REmap Case** is a cleaner climate-resilient pathway based largely on more ambitious, yet achievable, uptake of renewable energy and energy efficiency measures, which limits the rise in global temperature to well below 2 degrees and closer to 1.5 degrees above pre-industrial levels and is aligned within the envelope of scenarios presented in the **Intergovernmental Panel on Climate Change (IPCC)** Special Report on Global Warming of 1.5 ℃.

For more information about the REmap case and the data used in that case visit (link).

The analysis presented in this chapter is based in the **E3ME model**. E3ME is a macro-econometric model designed to assess global policy challenges. The model is owned and maintained by Cambridge Econometrics. For more information about E3ME model visit (link).

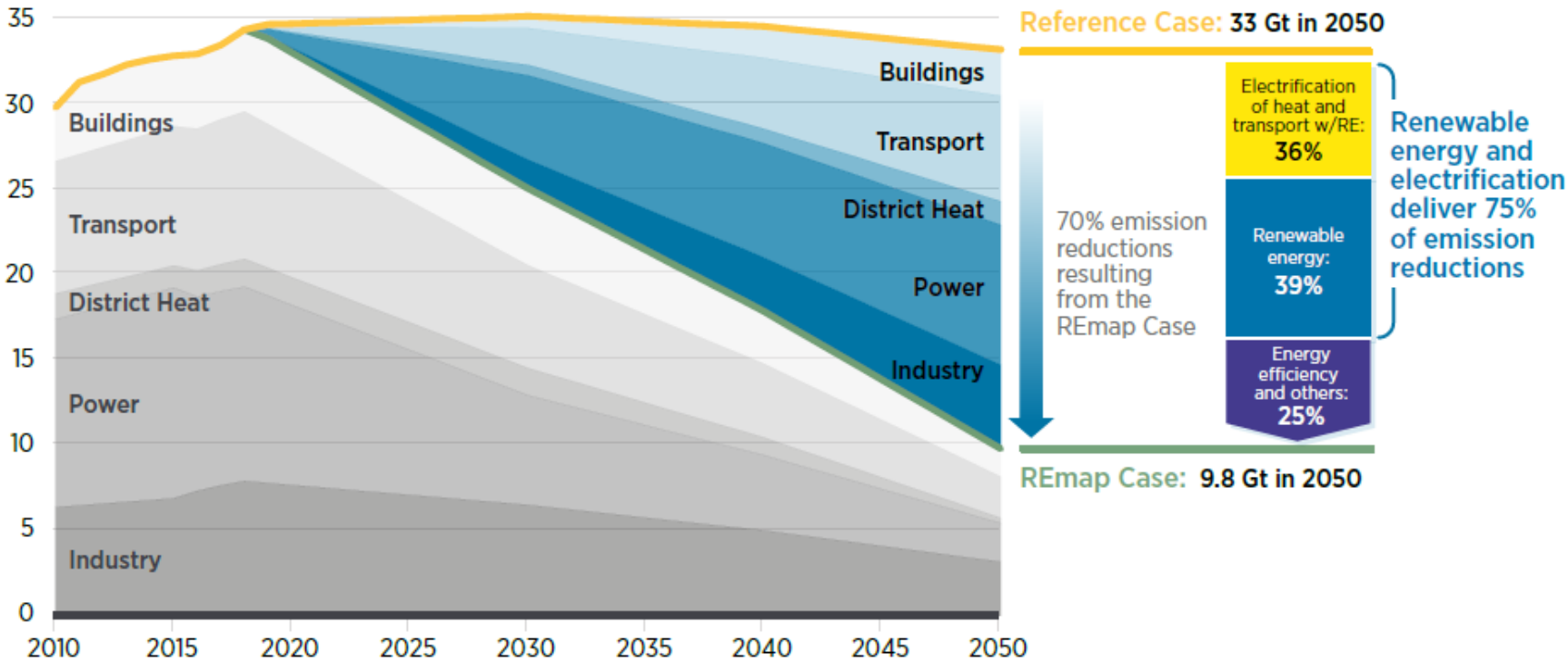
For more details and the **manual** of the model visit (link).

Energy-related CO2 emissions

Annual energy-related CO2 emissions under current and planned policies – the **Reference Case** – are expected to remain flat, at 33 Gt CO2 per year in 2050, but must be reduced by 70% to bring temperature rise to the well-below 2℃ climate goal – as in the **REmap Case** (figure next slide)

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% (figure next slide).

Energy-related CO2 emissions



Energy-related CO2 emissions

In 2010 about 9 Giga-tons of Carbon (GtC) were emitted from burning fossil fuels as 33 Giga-tons of CO2 gas.

How much is 9 Giga-ton? 9 billion tons or 9.000.000.000.000.000 grams. 9 Giga-tons is the weight of about 132 billion people. The amount of carbon we are putting into the atmosphere each year is equal to 20 times the weight of the current world population.

For more information about **annual CO2 emissions** data visit:

- International Energy Agency (link).
- Global Monitoring Laboratory (link).

For more information about the **carbon cycle** and the **greenhouse effect** visit Global Monitoring Laboratory (link).

An electrified future

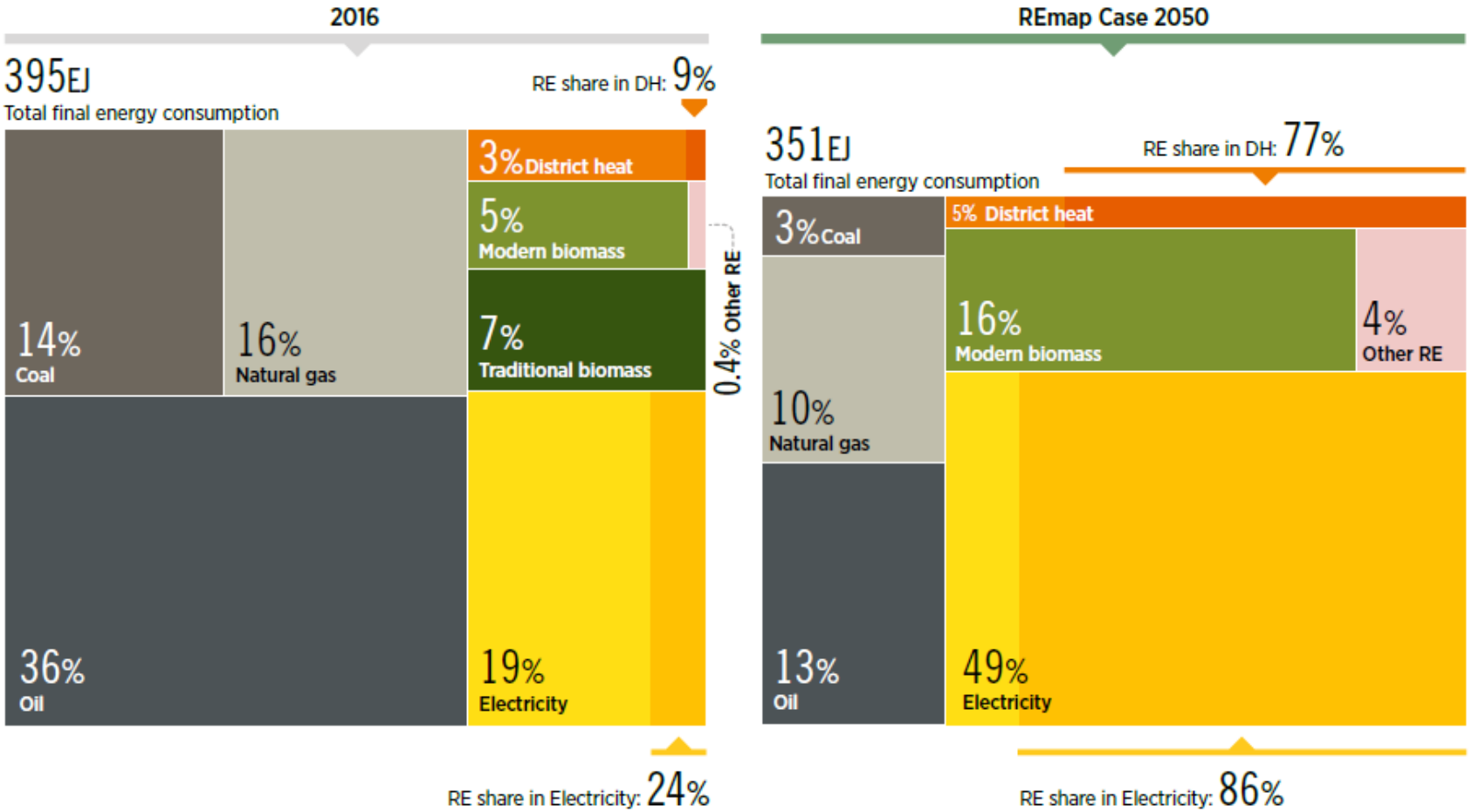
The increasingly **electric energy system** would transform how the power sector and demand interact (figure in the next slide).

The **share of electricity in final energy** would increase from just 20% today to almost 50% by 2050 (figure in the next slide)

The share of electricity consumed in **industry and buildings** would double

In **transport** it would need to increase from just 1% today to over 40% by 2050.

An electrified future

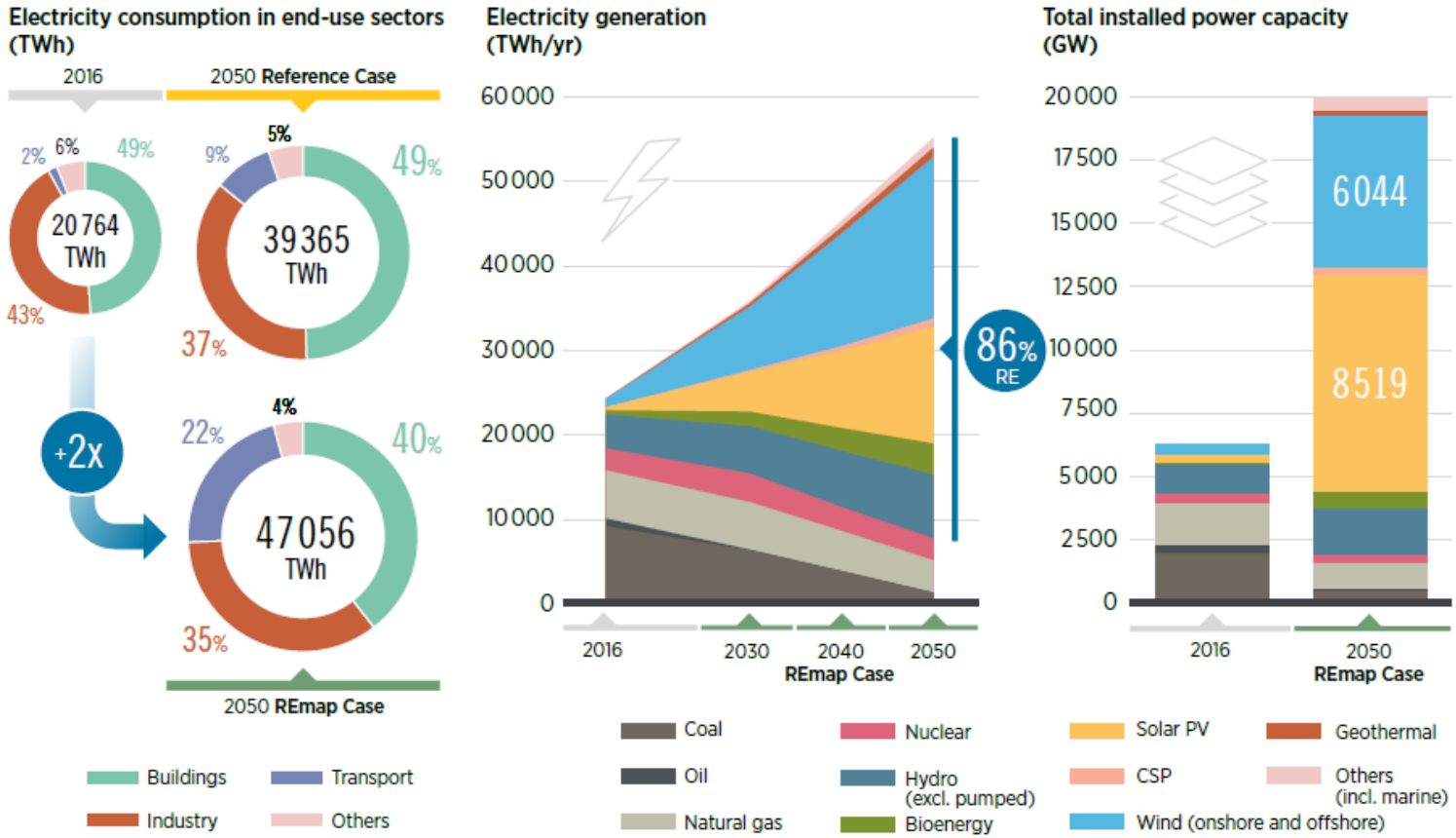


Note: For electricity use, 24% in 2016 and 86% in 2050 comes from renewable sources; for district heating, this share is 9% and 77%, respectively. DH refers to district heat.

The weight of renewables in electrification

By 2050, **solar power**, with 8 500 GW installed capacity, and **wind**, with 6 000 GW, would account for three-fifths of global electricity generation

Electricity consumption in **end-use sectors** will more than double from today's level (figure below).



Note: In electricity consumption, 24% in 2016 and 86% in 2050 is sourced from renewable sources. CSP refers to concentrated solar power

Investments

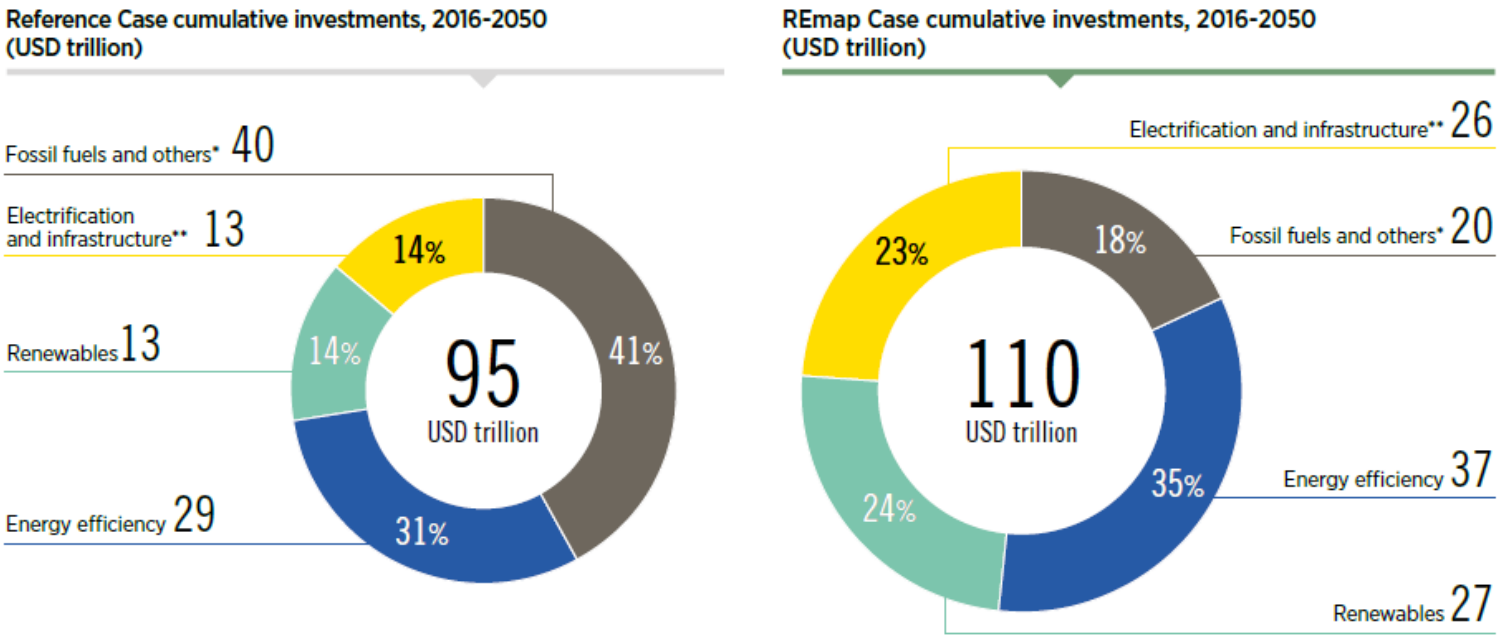
Cumulative investments in the energy system to 2050, including infrastructure and efficiency, will total almost USD 95 trillion in the Reference Case, and would increase to USD 110 trillion in the REmap Case (figure in the next slide)

Renewable power technologies are increasingly the **least-cost electricity supply options available**

The renewable energy market would grow quickly as **costs continue to decline**, as technologies improve and as innovation brings additional applications

An energy system based heavily on renewables would be different than past systems and would require significant investments in **power grids**, **complementary infrastructure** and **energy flexibility**

Investments



Notes: *includes nuclear, carbon capture and storage (CCS); **includes investments in power grids, energy flexibility, electrification of heat and transport applications as well as renewable hydrogen. "Energy efficiency" includes efficiency measures deployed in end-use sectors (industry, buildings and transport) and investments needed for buildings renovations and structural changes (excluding modal shift in transport). Renewables include investments needed for deployment of renewable technologies for power generation as well as direct end-use applications (eg. solar thermal, geothermal) USD throughout the report indicates the value in 2015.

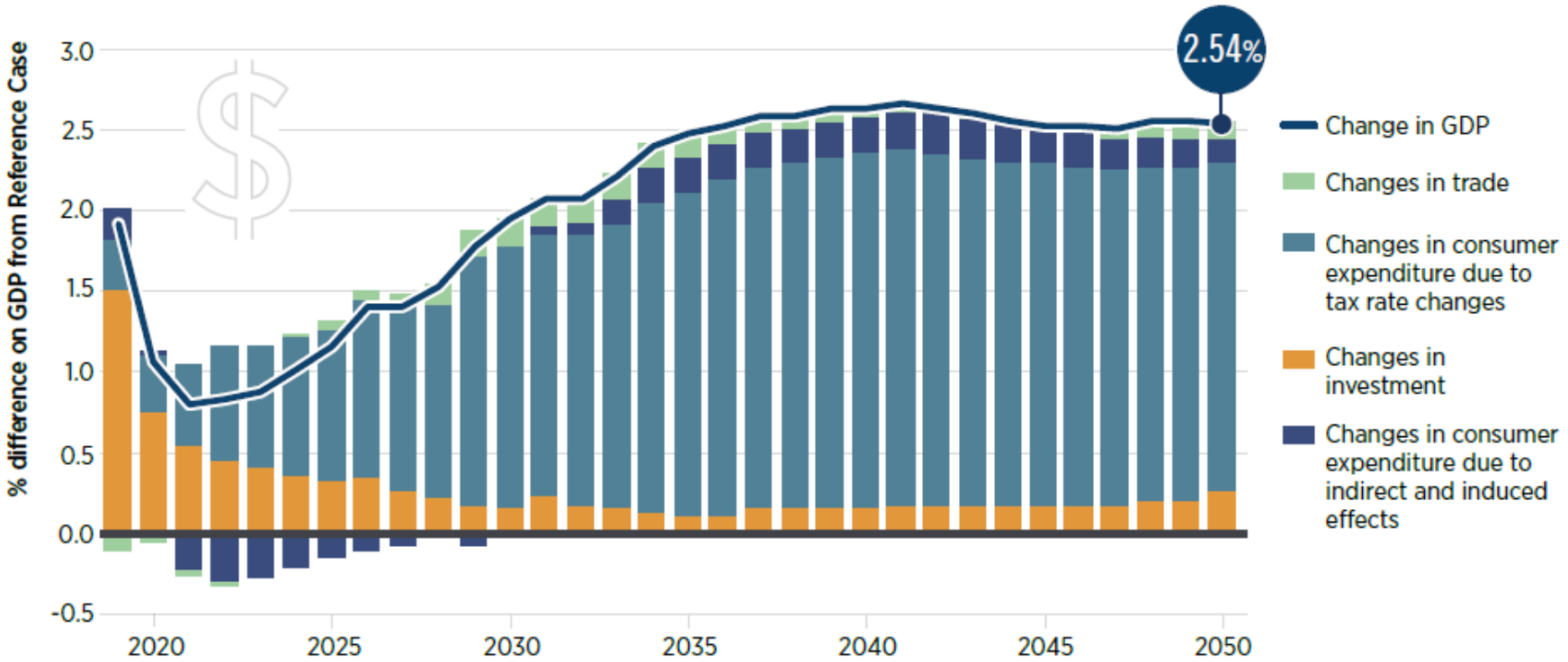
Energy-wide GDP and employment impacts

In the short term, the net positive impact on global GDP is due mainly to a front-loaded **investment** stimulus in renewable energy generation capacity, energy efficiency, and energy system flexibility to support the transition. The overall impact of this driver gradually fades in importance as time progresses (figure in the next slide)

Gains in **consumer expenditure** due to tax rate changes become the dominant factor in the evolution of GDP between 2022 and 2050. This driver captures the impact of the changes in government income due to carbon taxes, fossil fuel phase-out, changes in fossil fuel royalties and other taxes(figure in the next slide)

The **employment** gains are expected to be less significant than for GDP because additional demand in the global economy also pushes up real wages

Energy-wide GDP and employment impacts



Climate damages and its impact on GDP

The literature suggests that very important impacts from climate change can be expected on the performance of the socio economic system both in terms of **reducing global GDP** and **increasing inequality**:

- For the end of the century (year 2100) global **GDP reductions** are estimated at around 20% for a 2℃ global warming and 35% for a 5℃ global warming are reported (Burke et al, 2018).
- Climate damages will lead to **increased inequality** because much higher impacts can be expected in warmer regions, which often correspond to poorer countries (Burke et al, 2015).

Climate damages and its impact on GDP

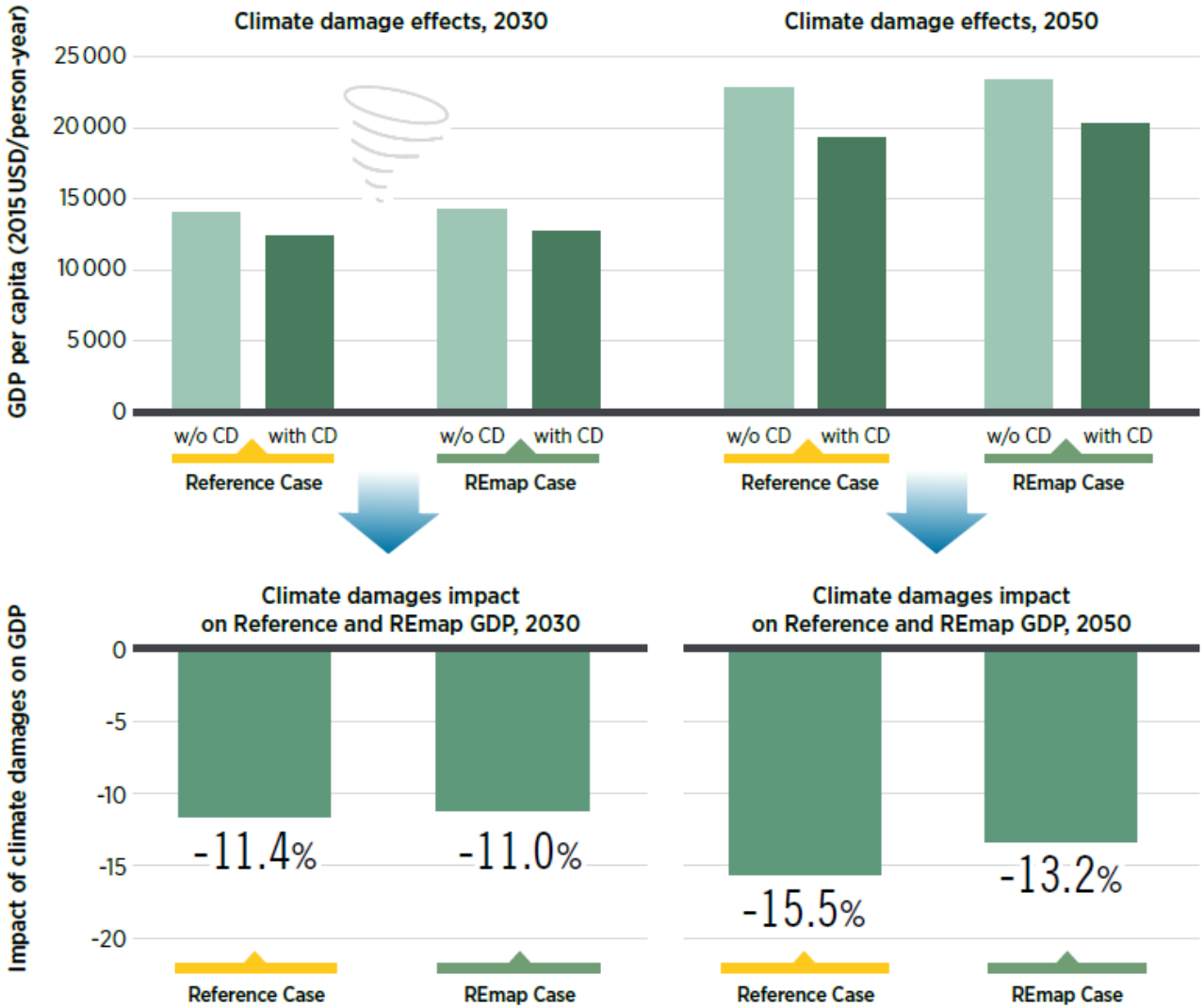
The upper graph in the figure in the next slide presents **per capita GDPs with and without climate damages**

Clear green bars represent the **per capita GDP without taking into account climate** damages, while dark green bars represent the **per capita GDP once climate damages** are factored in

As it can be seen both REmap and Reference cases experience a **significant reduction in GDP** when climate damages are included in the macroeconomic modelling

To better understand these reductions, the lower graph in the figure in the next slide presents the percentage reduction in GDP when **climate damages are included**, showing how important are the GDP reductions attributable to climate change

Climate damages and its impact on GDP



Climate damages and its impact on GDP

What does the applied climate damage methodology does not include? The results obtained can be considered conservative, because there are several ways through which climate change can negatively impact the economy that are not captured by it:

- **Sea level** rise and increased incidence of extreme weather events (flooding, draughts, tropical cyclones, wildfires...).
- **Disrupted trade** and modified trade dynamics based on modified power positions, where regions with higher damages on GDP (Global South) experience losses in trade balance, and winners (Global North) use the advantageous situation to impose trade agreements.
- **Social conflict** effects associated to disruption and increasing inequality.
- **Cross-country spillovers** associated to climate change that would produce higher economic impacts (for example, supply chain interruptions/alterations, trade effects...)

Action need now. Overview

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

   - Develop power systems that provide a high level of technical **flexibility**
   - Better **market signals** are needed to enable flexibility resources to come into play to cope with the uncertainty and variability of variable renewable energy (VRE) generation. Examples include real-time variable pricing and shorter trading intervals
   - Power markets will need to be redesigned to enable the **optimal investments** for systems with high levels of VRE and enable sector coupling

2. **Digitalisation** is a key enabler to amplify the energy transformation

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

Action need now. Overview

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

5. **Supply chains** are key to meet growing demand for sustainable **bioenergy**.

- **Bioenergy** must be produced in ways that are environmentally, socially and economically sustainable. There is a very large potential to produce bioenergy cost-effectively on existing farmland and grassland, without encroaching upon rainforests, and in addition to growing food requirements.
- **Biomass-based industries** that generate ready-to-use biomass residues – such as pulp and paper, lumber and timber, and food – are fundamental in the transition.
- In sectors such as aviation, shipping and long-haul road transport, **biofuels** might be the main or only option for decarbonisation for years to come.

Action need now. Power

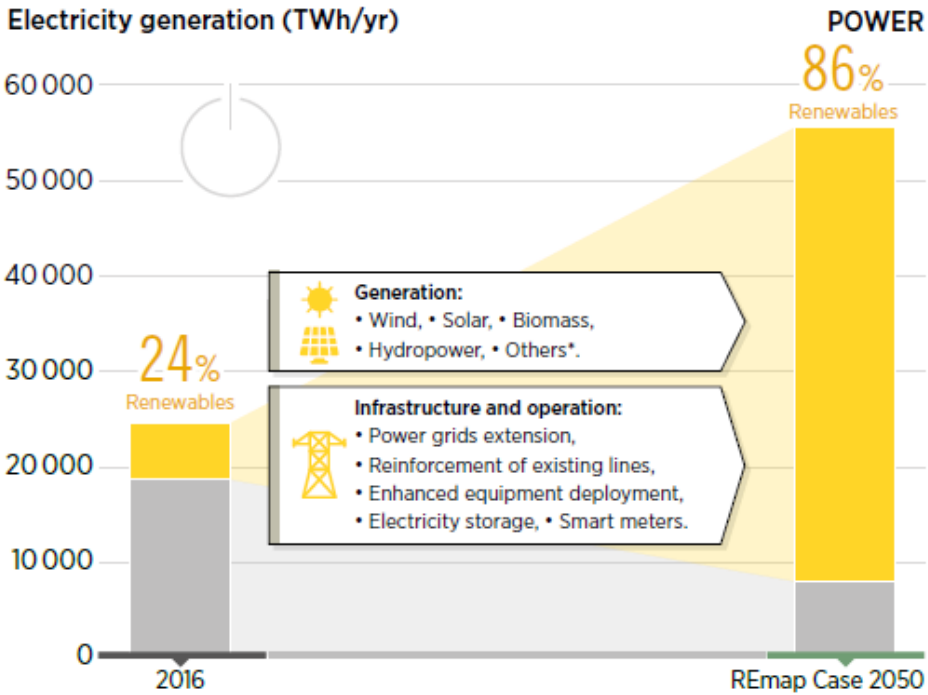
- **Accelerate renewables capacity additions**. In particular, identify and map renewable energy resources and develop a portfolio of financeable projects
- **Plan for the power sector** to accommodate increasing shares of variable renewable energy
- Support the deployment of **distributed energy resources**. In particular, incentivise energy consumers to become prosumers

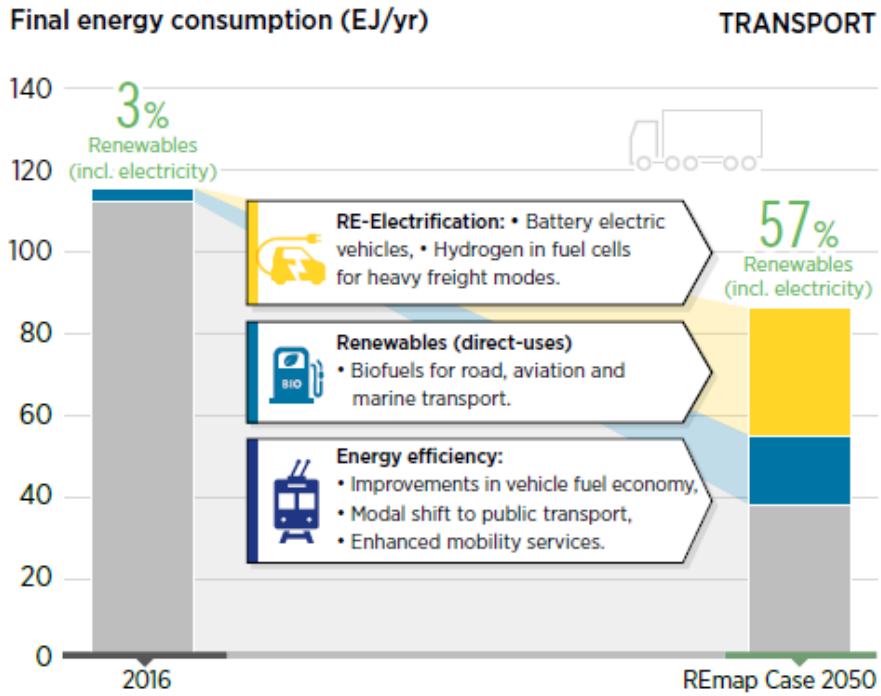
Action need now. Transport

Reduce the energy need for transport

- By deploying **advanced digital communication technologies** to reduce the transport needs (eg. teleconferencing over travelling) and to **improve efficiency of transport** by better utilizing the assets (eg. re-routing due to traffic)
- By **promoting mobility services**, e.g., promote vehicle sharing and autonomous driving

Action need now. Power and transport





Action need now. Industry

1. **Reduce energy consumption in industries**
   - By promoting actions towards **circular economy** (material recycling, waste management, improvements in materials efficiency and structural changes such as reusing and recycling)
   - By incentivising and adopting best available technologies (BAT) and **efficiency standards**

2. Enable corporate sourcing of renewables by supporting a credible and **transparent system for certification** and tracking of renewable energy attributes

3. Accelerate the deployment of **low-carbon technologies** in industrial process heating.

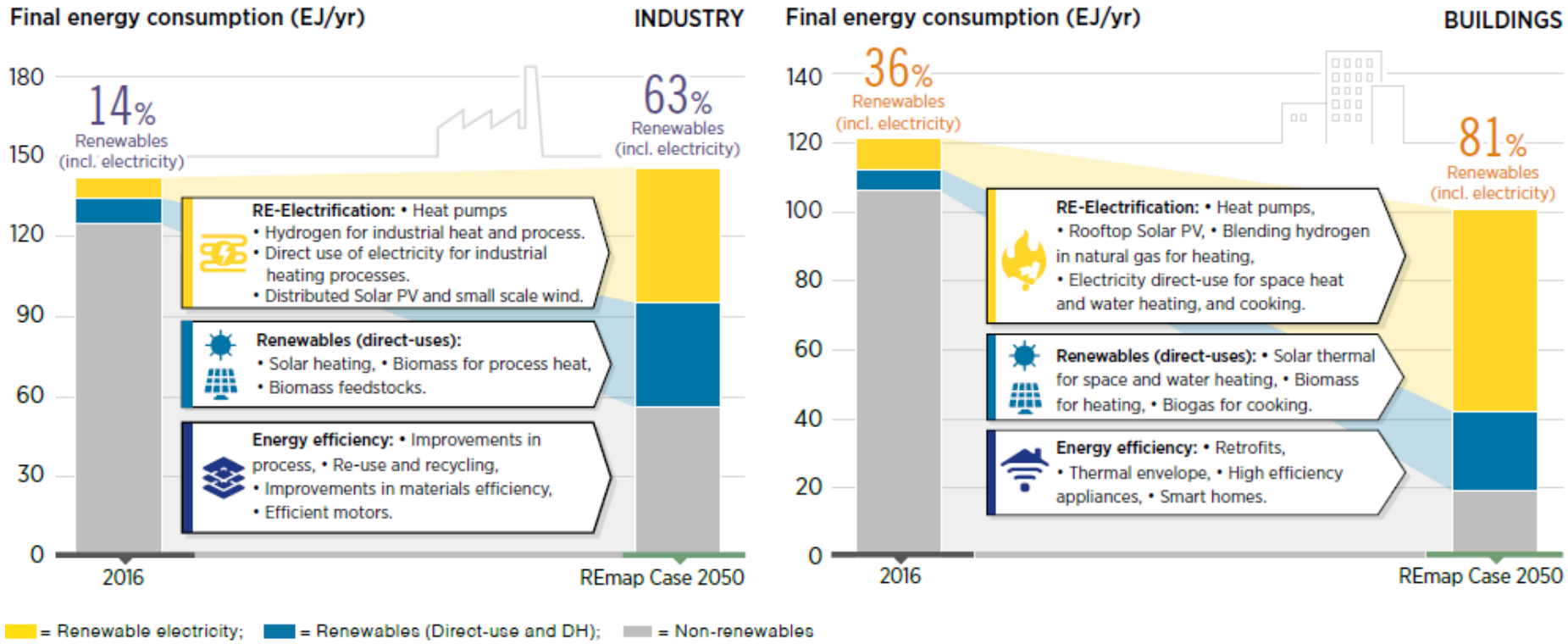
Action need now. Buildings

1. **Reduce energy consumption in buildings**
   - By establishing and **improve energy efficiency building codes and standards** (incl. appliances (eg. air conditioners), lighting (eg. LED lights) and equipment (eg. efficient boilers))
   - By adopting programmes for **retrofitting/renovation** including financing schemes

2. Support and foster the deployment of distributed energy resources by removing regulatory barriers for **prosumers** that restrict them from taking an active role in the energy system transformation

3. Scale up renewable share uptake in the building sector by promoting **low-carbon heating technologies**: heat pumps, solar heating, modern bioenergy for heating). Apply these renewable technologies for district heating.

Action need now. Industry and buildings



Sector coupling

Sector coupling refers to the idea of interconnecting (integrating) the **energy consuming sectors** - buildings (heating and cooling), transport, and industry - with the **power producing sector**. Making electricity the default form of energy in these sectors would be a step towards what is sometimes referred to as an "all-electric world."

For more information about sector coupling visit:

- Journalism for the energy transition (link 1).
- IRENA, sector coupling (link 2).

Supply chains

Supply chain activities involve the transformation of natural resources, raw materials, and components into a finished product that is delivered to the end customer.
For more information about supply chains visit:

- Wikipedia (link 1).
- Investopedia (link 2).

Questions to summarize the chapter

1. Carbon emissions must be reduced to 10 GT per year in 2050. Which are the **three main ways to reduce carbon emissions**?

   Electrification, introduction of renewable energy and energy efficiency

2. Which are the **four sectors** where carbon emissions need to be more effective?

   Power sector, industry sector, transport sector and building sector

3. The share of electricity in the energy production will pass from 20% to 80%. Which **share of electric production will be renewable**?

   The 86% of the electricity will be produced by using renewable energy

4. Which will be the **share of electricity use by sector**?

   40% in the building sector, 33% in the industry sector, 22% in the transport sector

Questions to summarize the chapter

5. In the **power sector**, the renewable share will pass from 24% to 86%. Can you enumerate the main **sources of renewable production**?
   Solar, wind, biomass and hydropower

6. In the **transport sector**, the renewable share will pass from 3% to 57%. Can you enumerate the **main changes in that sector**?

   EV, hydrogen for heavy freight modes, biofuels for road, aviation and marine transport

7. In the **industry sector**, the renewable share will pass from 14% to 63%. Can you enumerate the **main changes in that sector**?

   Hydrogen for industrial heat and process; direct use of electricity and renewables for industrial heating processes

8. In the **building sector**, the renewable share will pass from 36% to 81%. Can you enumerate the **main changes in that sector**?

   Renewables for heating, and electricity; biogas for cooking; increase in efficiency

Competition Policy and European Green Deal

Frans Timmermans

1. Of the EU recoverage package, which proportion will be **invested** in **green energy (climate policy)** and **digitalization**?

   30% will be invested in green economy and 20% will be invested in digitalization. The rest will be invested in sectors that foster digitalization and the adoption of a green economy

2. Which are the main sectors that could be **more problematic to de-carbonize**?

   The building, the transport and the agriculture sectors

3. Which are some of the **policies** that could be implemented to green the economy?

   Price on carbon emissions, regulation predictability and long-term stability

Competition Policy and European Green Deal

Pedro Size Vieira

1. Which are the **four (five) main objectives** of the current Portuguese government?

   Demographic change, digitalization, inequalities, green economy and biodiversity

2. Which are the main **technologies** used to promote the electrification of the country? Which will be the **share of renewable energy** production and consumption in Portugal in the next years?

   The technologies to produce electricity will be hydroelectric, wind and solar. The share of renewables in production is the 60% and the share of renewables in consumption is 40%

Competition Policy and European Green Deal

Sven Giegold

1. To foster the adoption of green technologies, Sven Giegold introduces the concept of fair price. Could you explain which policies should by implemented to obtain **fair prices**?

   First, the subsidies on pollution technologies should by phased out. Second, the pollution technologies need to internalize their externalities on society

2. Which are the policies to be implemented to foster the **investments in green technologies**?

   First, state aids in critical technologies, that are still not mature to be competitive. Second, to ban the subsidies to fossil fuels, and fossil fuels infrastructure

3. Which are the policies to mitigate the **impact of digitalization on carbon emissions**?

   Digitalization should be treated as a "quasi-infrastructure" and should be taxed according with "quasi-infrastructure" taxation

Competition Policy and European Green Deal

Philippe Aghion

Philippe Aghion claims that **markets are not able to promote green innovation** by themselves, since firms tend to be conservative

1. Which are the main **State policies** to foster green innovation?

   Carbon taxes, carbon prices, subsidies and incentives similar to arpa-e in USA

2. Which are the **main driver in the civil society** that foster green innovation?

   The societies in which consumers demand "green products" creates the conditions for green innovations, since the firms need to compete to attract those consumers

Competition Policy and European Green Deal

Mechthild Wörsdörfer

1. Which are the share of **carbon emissions by sectors**?

   40% CO2 emissions in the power sector, 25% CO2 emissions in the transport sector, 20% in the industry sector, the rest in other sectors

2. Which are the **main four economy areas** to green the economy?

   First, EV sales should move from 3% nowadays to 100% in 2050. Second, the heating system need to be electrified. Third, energy intense industries (cement, steel, chemistry) need to be electrified. Fourth, the building stock need to increase its efficiency (currently, the 75% is inefficient)

3. Which are the policies to foster **green innovation**?

   The 50% of the 400 different types of technological innovations required to green the economy are still not mature to be competitive. It is necessary State aid to foster green innovation