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Eight steps to interpret transition scenarios

Authors: Aurore **Colin** | Charlotte **Vailles** | Romain **Hubert**

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The following framework is extracted from the report "Understanding transition scenarios - Eight steps for reading and interpreting these scenarios". Based on the elements presented on this report on the construction process and components of transition scenarios, it summarises the main steps to follow when reading and interpreting these scenarios, as well as their key parameters. It is then applied to a selection of five scenarios.

1. Framework for reading transition scenarios

1 Identifying the context in which the transition scenario was developed

- **Issues**: The context in which the scenario was developed, the vision of its developer and its purpose guide the approach adopted for the scenario as well as the choices made during its construction – choices that largely determine the results of the scenario. Before considering the content of the scenario, it is therefore important to understand the context in which it was created, by which organisation and for which purpose. Moreover, it is important to familiarise with the vision of the transition described by the scenario (inclusion of targets other than the climate target, description of global/fragmented climate action, identification of an optimal pathway – following one or more criteria – to achieving the climate target, etc.).
- **Information/parameters to be identified**: the organisation that produces the scenario, its purpose(s), the date and context of publication, the frequency of scenario updates, the broad lines of the transition described by the scenario.

2 Identifying the level of information available on the scenario

- **Issues**: Depending on the context of their development, scenarios do not always use the same medium: although they very often take the form of written reports, these reports vary in length, detail and technicality depending on the scenario. Sometimes a summary is made public, while the detailed report is not available to all. Information on the methodology – in particular the model – and the data sources used are sometimes made public, along with tables or graphics presenting the results. The level of information available on the scenario will condition the use that can be made of it.

  ⚠ The information available on the scenario depends on the medium through which the results are presented, but also on the scope and granularity of the model used. In addition to the results made public, more disaggregated data may exist in the model.
- **Information/parameters to be identified**: the medium of publication, the existence of methodological annexes or tables of results, the scope (geographical, sectoral, time horizon), the granularity of results (geographical, sectoral, temporal).

3 Understanding the socio-economic context of the transition described by the scenario

- **Issues**: The future socio-economic context considered in the scenario – which corresponds to world changes (demographic, economic, geopolitical, institutional, etc.) exclusive of the climate target – may be more or less conducive to reducing GHGs. Understanding this context is essential in order to identify the challenges of the transition described in the scenario

  ⚠ These changes can be explored in a baseline scenario associated with the transition scenario. Since the results of the transition scenario are sometimes presented as a differential in relation to this baseline scenario, it is essential to fully understand the assumptions included in the latter.

- **Information/parameters to be identified**: the existence of a baseline scenario and its key assumptions, assumptions about the socio-economic context (changes in economic growth or its determinants, population, lifestyles, technological progress, the rate of urbanisation, the rate of inequality, the degree of globalisation/ international cooperation, etc.).

4 Identifying the climate target and the distribution of efforts over time

- **Issues**: The trajectory and results of the transition scenario are conditioned by a climate target, usually expressed as a limit on global warming by 2100. This target can be taken into account in different ways in the scenario (compliance with a carbon budget, comparison of emissions trajectories with baseline trajectories such as the RCPs, use of a climate model). The probability associated with achieving the target gives an additional indication of the ambition of the scenario. Moreover, the emissions reduction trajectory provides information about the distribution of efforts over time.

  ⚠ It should be noted that scenarios in which reduction efforts are further in the future generally use negative emissions technologies to meet the climate target.

  ⚠ For scenarios with a time horizon ending before 2100, it is important to determine whether assumptions are made/accepted about changes in GHG emissions over the period not covered by the scenario and to understand their implications in terms of the reduction efforts required, possible shifts away from the changes described by the scenario, and the use of negative emissions technologies. These assumptions about changes in emissions beyond the time horizon of the scenario determine the levels of emissions reductions required in the scenario. They are not always explicit.

- **Information/parameters to be identified**: the climate target set, the probability associated with it, the way in which it is taken into account in the scenario, changes in the GHG emissions trajectory, the assumptions made/accepted about changes in GHG emissions beyond the period covered by the scenario.

5 Identifying the weight given to the different drivers of the transition and the associated assumptions

- **Issues**: Each scenario is based on drivers of change – mainly political, technological and behavioural – that serve to implement the solutions identified at Step 7. Depending on the scenario, the weight given to the different drivers is not the same. Identifying the drivers underlying the scenario helps to understand how the transition – and the far-reaching changes it implies – are explained by the scenario developer.

  ⚠ The weight given to the different drivers of the transition can generally be understood through the story told around the scenario, which combines assumptions and results in order to create a coherent narrative about the transition. This story, which enables the developer to justify the results of the scenario and to explain how the different mitigation solutions are implemented, increases the credibility of the scenario[1].

  ⚠ The carbon price does not always represent the establishment of an explicit carbon price through a tax system or an emissions trading scheme. It sometimes represents a shadow price that reflects the emissions reduction efforts required over time to meet a specific objective.

- **Information/parameters to be identified**: the measures/regulations/policies supporting the implementation of mitigation solutions, the value and significance of the carbon price, the behavioural changes and technological progress needed for the transition.

6 Analysing the geographical and sectoral distribution of reduction efforts

- **Issues**: Many scenarios include elements on changes in emissions according to the emitting sectors: **building, transport, industry, power generation, agriculture**. The far-reaching changes implied by emissions reductions are not driven by the same sectors depending on the scenarios. The geographical distribution of emissions reductions – and therefore of mitigation efforts – also varies from one scenario to another. The distribution of

1 For example, an increase in the vehicle load factor in a scenario can be explained by the implementation of an ambitious carpooling policy and regulations on empty running for heavy goods vehicles.

efforts between sectors/countries derives from the dynamics of the model and the input assumptions of the scenario[2].

⚠ Emissions trajectories are not always comparable between scenarios: the **emitting sectors** and the **types of GHGs** taken into account vary. This is partly due to the model used to quantify the scenario.

⚠ It is important to understand the assumptions made about **changes in GHG emissions and in the sectors not represented in the scenario** (and the underlying model), which condition the emissions reduction efforts needed in the sectors covered by the scenario[3]. Likewise, in the case of a regional/national scenario, it is important to understand the assumptions made about **emissions reductions in the rest of the world**.

- **Information/parameters to be identified**: the GHG emissions trajectory for the scenario, changes in emissions by sector/geographical area, assumptions about changes in emissions in the sectors/geographical areas not covered by the scenario (rarely indicated).

7 Identifying the solutions deployed to reduce GHG emissions and the associated technologies

- **Issues**: The weight given to the different mitigation solutions differs according to the scenario. It reflects a specific vision of the transition, which derives from the approach and the vision of the scenario developers. The mitigation solutions considered also depend on the scope of the model used and the sectors represented.

  ⚠ The representation of mitigation solutions in the scenario – and therefore the information available on these solutions – depends on the model used, its scope, its approach (techno-economic, with a more or less detailed representation of technologies, or more macro-economic) and its granularity.

- **Information/parameters to be identified**: examples of parameters enabling the identification of solutions deployed and their relative weight, by major category of mitigation solutions:
  - **Managing demand for energy and GHG emissions-intensive materials**: the share of emissions reductions due to energy efficiency globally and by sector; changes in primary energy consumption; changes in energy consumption in the different energy end-use sectors;
  - **The decarbonisation of the energy mix**: the share of the different renewable energies in the energy mix, changes in the share of electricity in final energy consumption, the share of nuclear in the electricity mix, the rate of deployment of CCUS technologies;
  - **Managing emissions from the agricultural system**: changes in emissions from the agricultural sector, changes in the consumption of meat;
  - **The use of negative emissions**: the amount of negative emissions, the BECCS capacities in place, the forest sinks mobilised.

The qualitative story accompanying the scenario can also be useful in understanding the importance of the different mitigation solutions.

8 Identifying the macro-economic consequences of the transition

- **Issues**: Beyond the technological and political challenges, the macro-economic implications of the transition (investments, impacts on employment and growth, etc.) assessed in the scenario are important in order to better understand the economic challenges linked to the changes required for the transition.

  ⚠ Scenarios do not always provide information about the macro-economic implications of the transition; this depends in particular on the type of model used to quantify the scenario. Some parameters must therefore be interpreted differently depending on the way in which they were generated (for example, if changes in economic growth are set as an input assumption by the developer of the scenario, their value does not include the economic consequences of the transition).

  ⚠ The macro-economic impacts of the transition – when they are given in the scenario – are often presented as a differential in relation to a baseline scenario. In most cases, this scenario – and the transition scenario – do not include the impacts of climate change.

- **Information/parameters to be identified**: changes in economic growth and the impacts of the transition on economic growth, the investments required for the changes described in the scenario, the consequences of the transition on employment, changes in electricity or energy prices for end consumers.

2 This distribution may, for example, derive from the minimisation of transition costs with an optimisation model. It may also include other criteria, such as the convergence of per capita emissions.

3 This point of vigilance also applies to sectors represented in a very simplified manner, for which the assumptions are not necessarily explicit in the scenario – even if this is more difficult to detect.

2. Detailed review of a selection of transition scenarios

The previous framework is applied to a selection of five publicly-available transition scenarios, which are intended to be representative of the range of existing scenarios.

STEP 1

IDENTIFYING THE FRAMEWORK IN WHICH THE TRANSITION SCENARIO WAS DEVELOPED

	Organisation	Date of publication	Frequency of updates	Purpose(s) of the scenario and broad lines of the transition presented
IEA - SDS scenario	The International Energy Agency (IEA) is an **intergovernmental organisation created by the OECD following the first oil crisis**, with the initial goal of ensuring energy security for the OECD member countries, in **particular concerning oil supply. Its role has since expanded: it informs and advises states about energy issues**, providing extensive data and numerous analyses.	**2018**	Annual	The World Energy Outlook (WEO) is published with a view to presenting **scenarios of changes in energy markets** in the medium and long term, according to public policies that affect the energy sector. *Goal of the SDS:* • Describing changes in the energy system in line with **universal access to modern energy** services by 2030, and consistent with the **goals of the Paris Agreement** as well as with **reducing air pollution**.
Greenpeace - Advanced Energy Revolution scenario	Greenpeace is an **NGO working for the protection of the environment and biodiversity**. Since 2005, it has been producing future energy system scenarios to address the challenges of environmental sustainability.	**2015**	Five editions of the Energy Revolution report have been published since 2005.	*Goals:* • Presenting a pathway in line with ending energy-related CO_2 emissions, achieving a **100% renewable energy system and phasing out nuclear energy**. • Showing that such a future is **feasible and desirable** by describing its implications and the conditions for its achievement.
IRENA - REmap scenario	IRENA is an **intergovernmental organisation** whose goal is to inform countries about the development of renewable energy (political, economic, financial and technological implications) and to promote the widespread adoption and sustainable use of all types of renewable energy.	**2019**	Annual updates since its creation (in 2017).	*Goals:* • Presenting **a pathway to the decarbonisation of the global energy system**, largely based on the **deployment of renewable energies**. • Informing policymakers about the possible solutions for implementing the climate targets set by the Paris Agreement.
BP - Rapid Transition scenario	British Petroleum (BP) is a long-standing **oil company** of British origin	**2018**	Annual	*Goals:* • Exploring changes in the energy system **compatible with the goals of the Paris Agreement**. • Informing the **strategies of the oil company**.
Low Energy Demand (LED) scenario	The scenario was created by a group of researchers associated with the **International Institute for Applied Systems Analysis (IIASA)**. This research Institute conducts studies to analyse global challenges such as climate change. The goal of its studies is to help policymakers to implement science-based policies.	**2018**	---	*Goals:* • Presenting a transition scenario based on a **substantial reduction in final energy demand** that stands out from most scenarios proposing solutions for energy supply and production (decarbonisation of the energy mix, development of large-scale renewable projects). • Informing policymakers, showing that such a future **is not unrealistic** and what it implies.

STEP 2 IDENTIFYING THE LEVEL OF INFORMATION AVAILABLE ON THE SCENARIO

	Scenario medium	Existence of methodological annexes and/or data tables	Time horizon	Geographical and sectoral scope and GHGs considered	Granularity of results[a]		
					Time step	Geographical granularity	Sectoral granularity
IEA - SDS scenario	Scenario published in the **World Energy Outlook** (WEO), a report of several hundred pages.	A **methodological annex** describes the model; tables of assumptions and results are given at the end of the report and can be downloaded in Excel format on the IEA website.	**From 2017 to 2040**	*Geographical scope:* the world *Sectoral scope:* the energy system *GHGs:* Energy-related CO_2 emissions	Most of the results are given in 5-year time steps.	Most of the results are given for the following geographical areas: The world, North America, Central and South America, Europe, Africa, the Middle East, Eurasia and Asia Pacific. Some results are given for individual countries or groups of countries, for example the European Union (EU).	The results are given for industry, transport, building, and the production of electricity and heat.
Greenpeace - Advanced Energy Revolution scenario	Scenario published in **Energy [R]evolution: a sustainable future for all**, a detailed report of several hundred pages. NB: in the executive summary, the scenario is called “Energy Revolution”.	There are no annexes, all information is provided in the long version of the report, including the tables of results at the end of the report.	**From 2012 to 2050**	*Geographical scope:* the world *Sectoral scope:* the energy system *GHGs:* Energy-related CO_2 emissions	Most of the results are given in 10-year time steps.	Most of the results are given for the following geographical areas: the world, OECD Europe, OECD North America, Eastern Europe and Eurasia, Latin America, Africa, Middle East, China, India, and the other Asian countries.	The results are generally given for industry, transport, and the production of electricity and heat.
IRENA - REmap scenario	Scenario pu-blished in the 2019 edition of the report **Global Energy Transforma-tion: A road-map to 2050**, a report of around 50 pages.	Methodological elements and data about the scenario (downloadable in Excel format) are available on the **IRENA website**.	**From 2018 to 2050**	*Geographical scope:* the world *Sectoral scope:* the energy system *GHGs:* Energy-related CO_2 emissions	The results are given in 10-year time steps.	The results described by the scenario are for the world –results downloadable in Excel format are given by geographical area (North America, Latin America, EU28, rest of Europe, sub-Saharan Africa, Middle East and North Africa, East Asia, Southeast Asia, rest of Asia).	The results are given for industry, transport, building, and the production of electricity and urban heat.
BP - Rapid Transition scenario	Scenario published in **the Energy outlook 2019**, a report of around 70 pages including numerous figures.	Tables of data are available at the end of the report (in the Annex) and in downloadable Excel format on **the BP website**.	**From 2017 to 2040**	*Geographical scope:* the world *Sectoral scope:* the energy system *GHGs:* Energy-related CO_2 emissions	The results in the scenario are given for 2040 or as an annual percentage change between 2017 and 2040.	Most of the results are for the world, some results are given by geographical area (US, EU, other OECD countries, China, India, rest of Asia, Middle East, Russia, Brazil, other non-OECD countries).	The results concerning final energy consumption are given by sector: indus-try, building, transport.

STEP 2 IDENTIFYING THE LEVEL OF INFORMATION AVAILABLE ON THE SCENARIO *(CONT.)*

	Scenario medium	Existence of methodological annexes and/or data tables	Time horizon	Geographical and sectoral scope and GHGs considered	Granularity of results[a]		
					Time step	Geographical granularity	Sectoral granularity
Low Energy Demand (LED) scenario	Scenario available online in the form of an article **published in "Nature"** of around 10 pages, including a table summarising the main assumptions and results of the scenario.	The scenario is accompanied by a detailed **complementary report** and a **large database** available online (free registration).	**From 2020 to 2050** (with an exten-sion to **2100**)	*Geographical scope:* the world *Sectoral scope:* the energy system, industry, the land-use and forestry sector, waste. *GHGs:* All GHG emissions.	The time step is usually 10 years (especially for the database results).	The results are given for the world, the North and the South.	The data on energy are by sector (residential and commercial building, industry, transport and electricity production). The data on GHG emissions are by more aggregated sector (energy and industrial processes, waste, land-use and forestry sector).

a. The disaggregation presented here corresponds to that of the results given in the main report. It does not predict the granularity of the model used to quantify the scenario, and therefore the existence of more detailed results. For example, the IEA model used for the SDS has an annual time step and divides the world into 25 geographical areas.

STEP 3

UNDERSTANDING THE SOCIO-ECONOMIC CONTEXT OF THE TRANSITION DESCRIBED BY THE SCENARIO

	Baseline scenario	Economic growth (calculated from GDP in PPP)[a]	Population change	Other change(s)
IEA - SDS scenario	Yes - the **New Policies Scenario (NPS)**. This central scenario of the WEO describes changes in energy markets, taking account of the climate policies already implemented and those planned by states. **Emissions continue** to increase in this scenario.	Average annual growth rate of **3.4%** between 2017 and 2040. It is driven by China, India, Southeast Asia and Africa. It is lower in the EU (1.6%/year on average).	9.2 bn in 2040.	**Rate of urbanisation increasing** everywhere, especially in Asia Pacific and Africa. Few elements about socio-economic changes other than economic growth and population.
Greenpeace - Advanced Energy Revolution scenario	Yes - called the Reference Scenario, it is based on **the Current Policies Scenario** (CPS) presented in the WEO 2014 by IEA. This baseline scenario includes only climate and energy policies already implemented.	Average annual growth rate of **3.1%** between 2017 and 2040. Growth is driven by China, India and the other developing countries. The economic weight of the OECD decreases.	9.5 bn in 2050.	Few elements about socio-economic changes other than economic growth and population.
IRENA - REmap scenario	Yes - called the **Reference Case**. It includes the energy and climate policies implemented or planned in each country, especially the nationally determined contributions under the Paris Agreement that have been translated into national policy.	In the baseline scenario[b] : average annual growth rate of **2.4%** between 2019 and 2050. Average annual growth rate including some climate impacts on the economy: **1.8%** between 2019 and 2050.	9.7 bn in 2050.	Few elements about socio-economic changes other than economic growth and population.
BP - Rapid Transition scenario	Yes - called **the Evolving Transition (ET)**. This **central scenario** of the Energy Outlook assumes that policies, technologies and social preferences continue to evolve in a similar way as in recent years. **Emissions continue** to increase in this scenario.	Average annual growth rate of **3.2%** between 2017 and 2040.	9.2 bn in 2040.	Few elements about socio-economic changes other than economic growth and population.
Low Energy Demand (LED) scenario	No - the quantified parameters describing the socio-economic context, in particular population and economic growth, are accessible in the scenario database.	Average annual growth rate of **2.8%** between 2020 and 2050.	9.2 bn in 2050.	Five major changes: **improved quality of life, rapid urbanisation**, the development of new, **innovative energy services**, a more active role played by energy consumers, and innovation in **information and communication technologies**.

a. In all of these scenarios – except for the REmap scenario by IRENA –, GDP is an exogenous variable: it therefore includes neither the effects of the transition nor the impacts of climate change. The REmap scenario, on the other hand, gives a value for economic growth including certain climate impacts.

b. The growth rate in the REmap transition scenario is given in Step 8, which presents the macro-economic effects of the transition.

STEP 4 IDENTIFYING THE CLIMATE TARGET AND THE DISTRIBUTION OF EFFORTS OVER TIME

	Climate target set and probability associated with this target	Consideration of the climate target	Changes in the GHG trajectory (see Figure 15)	Assumptions about changes in GHG emissions beyond the period covered by the scenario
IEA - SDS scenario	**Compatibility with the Paris Agreement.**	The CO_2 emissions trajectory until 2040 is within the envelope of transition scenario trajectories from the world of research that are compatible with RCP2.6[a]. The IEA refers to the database https://tntcat.iiasa.ac.at/SspDb/	Energy-related CO_2 emissions peak in 2020 and decrease to **17.6 $GtCO_2$ in 2040**.	Maintaining the rate of emissions reductions beyond 2040 would make it possible to reach net zero emissions for energy-related CO_2 emissions by around 2070. It is noted that maintaining this reduction rate would require **major technological innovation**, in particular concerning **CCUS and negative emissions technologies**.
Greenpeace - Advanced Energy Revolution scenario	**Below 2°C.**	Achieving the climate target is justified by the emissions trajectory for the scenario, which reaches zero energy-related emissions in 2050.	Energy-related CO_2 emissions peak before 2020 – emissions are drastically reduced to **reach zero emissions in 2050.**	----
IRENA - REmap scenario	**Well below 2°C.**	Cumulative CO_2 emissions between 2015 and 2050 are below the carbon budget giving a 67% probability of limiting global warming to 2°C. Assumptions are made about changes in emissions not covered by the scenario (see Step 6).	Energy-related CO_2 emissions peak before 2020 – emissions are drastically reduced to reach **9.8 $GtCO_2$ in 2050**.	---
BP - Rapid Transition scenario	**Compatibility with the objectives of the Paris Agreement.**	The emissions trajectory for the scenario is within the envelope of trajectories of four other scenarios described as being compatible with the objectives of the Paris Agreement (the SDS by the IEA, the Sky scenario by Shell, the Renewal scenario by Equinor, and the illustrative P1 trajectory of the IPCC 1.5°C special report.	Energy-related CO_2 emissions peak before 2020, then emissions are reduced steadily to reach **18 $GtCO_2$ in 2040**.	The scenario cites changes needed to reduce remaining emissions after 2040. These include, for example, the **use of CCUS** and of **negative emissions** (BECCS), increased **electrification** in energy end-use, improvements in energy storage technologies, and the use of hydrogen and bioenergy.
Low Energy Demand (LED) scenario	**1.5°C without overshoot with a probability of more than 60%.**	A climate module (MAGICC) is used to estimate the degree of global warming. Moreover, the model used for the construction of the scenarios is constrained by a carbon **budget for 2020-2100 of 390 $GtCO_2$**.	GHG emissions peak in 2020, then emissions are drastically reduced to reach **9.4 $GtCO_2eq$** in 2050. CO_2 emissions **reach 2.7 $GtCO_2$ in 2050 and are negative from 2060.**	The scenario is extended in a stylised manner (with simplified assumptions) until 2100.

a. These scenarios explore combinations of different socio-economic narratives (the SSPs) and different radiative forcings represented by the RCPs (see **Box 12** and **Box 7**).

STEP 5

IDENTIFYING THE WEIGHT GIVEN TO THE DIFFERENT DRIVERS OF THE TRANSITION AND THE ASSOCIATED ASSUMPTIONS

	Political driver	Technological driver	Behavioural driver
IEA - SDS scenario	• **Many policies implemented in all sectors and all countries**, *e.g.* phasing out fossil fuel subsidies by 2035 for all countries, implementing stringent efficiency and emissions standards for power stations, industries, vehicles and new buildings. *Focus on the carbon price:* • The carbon price corresponds to an input assumption, and represents the **implementation of carbon pricing policies (taxes or markets)**, in addition to other measures. • For the developed countries: **from 63 $/tonne in 2025 to 140 $/tonne in 2040**; • For some emerging countries: **from 43 $/tonne in 2025** to **125 $/tonne in 2040**.	• Technological progress supported by the political driver.	• Little or no mention.
Greenpeace - Advanced Energy Revolution scenario	• **Strong international commitments** by states, with ambitious, legally binding objectives. • Implementation of **ambitious climate and energy policies** in all sectors, *e.g.* phasing out fossil fuel subsidies by 2020; • Strong political and social acceptability for renewable energies, but not for technologies with environmental and social sustainability issues: nuclear phase-out and non-use of BECCS/CCUS technologies. *Focus on the carbon price:* • Carbon pricing is recommended as a policy measure, but the price of carbon is not specified.	• Rapid technological progress supported by the political driver, especially for renewable technologies that are currently immature or not fully mature (*e.g.* hydrogen for vehicles, offshore wind, marine energy technologies) and grid technologies that enable integration of a high proportion of renewables in the electricity mix (*e.g.* smart grid or demand management technologies).	• Little or no mention.
IRENA - REmap scenario	• Implementation **of sectoral mitigation measures** (*e.g.* establishment of a minimum emissions standard for vehicles, ban on the construction of new coal-fired power stations). • Implementation of policies to establish an economic framework conducive to the rapid, large-scale deployment of renewable energies (*e.g.* price regulation policy, new tariff structures for electricity). *Focus on the carbon price:* • Implementation of carbon pricing mechanisms in industry, aviation, maritime transport and long-distance road transport: the value of carbon is not specified, however.	• Rapid technological progress supported by the political driver, helping for example to improve the digitalisation and flexibility of the power system, to increase the use of hydrogen for transport and industry, or the use of biofuels in aviation, maritime transport and long-distance road transport.	• Little or no mention.
BP - Rapid Transition scenario	• Implementation of sectoral policies and measures (*e.g.* the ban on installing new conventional coal-fired power stations at the global level from 2030, implementation of strict emissions standards for electrical appliances and new buildings). • Implementation of carbon pricing mechanisms. *Focus on the carbon price:* • The carbon price corresponds to an input assumption, and represents the implementation of carbon pricing policies (taxes or markets) in the different countries: • For the OECD countries: **from 25 $/tonne in 2025** to **200 $/tonne in 2040;** • For the non-OECD countries: **from 10 $/tonne in 2025** to **100 $/tonne in 2040.**	• Continuous technological progress in the field of renewable energy and carbon capture and storage. • Technological progress is stimulated and supported by different policies – alone, it will not be enough to sufficiently reduce emissions.	• Some marginal changes in behaviours and practices, linked in particular to the circular economy and to mobility.

STEP 5 IDENTIFYING THE WEIGHT GIVEN TO THE DIFFERENT DRIVERS OF THE TRANSITION AND THE ASSOCIATED ASSUMPTIONS *(CONT.)*

	Political driver	Technological driver	Behavioural driver
Low Energy Demand (LED) scenario	• Implementation of public policies to support and accelerate the **technological, institutional** (especially markets) **and behavioural changes** that are presented as the main drivers of the transition. *Focus on the carbon price:* • Shadow carbon price representing the cost of emissions reductions needed to achieve the climate target of: **90 $/t$CO_2$ in 2030**, increasing to **160 $/t$CO_2$ by 2050**, then to around **700 $/t$CO_2$ by 2100**.	• Rapid progress in information and communication technologies coupled with strong digitalisation. • Rapid innovation and improvement in decentralised, small-scale energy production, development of end-use technologies. • Non-development of CCUS and BECCS technologies.	• High aspirations to live in a healthy, unpolluted environment. • Consumer preferences for innovative, flexible services that are available on demand (*e.g.* shared objects and services). • Change in the role of energy consumers, who play an active part in energy production (*e.g.* development of self-consumption at household or district level).

STEP 6 ANALYSING THE GEOGRAPHICAL AND SECTORAL DISTRIBUTION OF REDUCTION EFFORTS

	Distribution between sectors (see Figure 16)	Assumptions about sectors/gases not represented	Distribution between countries/areas
IEA - SDS scenario	Emissions reductions primarily stem from the power sector, then from the transport sector. Slight reductions in other sectors.	CO_2 emissions from industrial processes and methane emissions linked to industrial processes and to energy reach 2.4 $GtCO_2eq$ in 2040. Emissions projections for the LULUCF[a] sector are taken from the OECD Baseline Scenario (2012b) – they decrease over time.	Emissions reduction efforts are greater for the developed countries (-4.5%/year on average for the OECD countries) than for the developing countries (-2%/year), with some exceptions such as China (-4.3%/year).
Greenpeace - Advanced Energy Revolution scenario	All sectors reach net zero emissions in 2050. Emissions from the power sector decrease sharply from 2020; for the other sectors, this decrease is slower until 2030, then very steady between 2030 and 2050.	---	All countries reach zero emissions in 2050, but the developed countries and Latin America have a higher reduction rate over the period 2015-2040 than the developing countries, especially the Asian countries including China and India – emissions from the latter continue to increase until 2030.
IRENA - REmap scenario	The power sector makes the greatest reduction efforts. The transport sector also makes substantial efforts.	• Assumptions for CO_2 emissions from industrial processes: 90 $GtCO_2$ of cumulative emissions between 2015 and 2050. • Assumptions for CO_2 emissions from the LULUCF[a] sector: cumulative emissions from the sector between 2015 and 2100 are close to zero (positive before 2050, zero in 2050, then negative after 2050).	North America, the European Union and East Asia make the greatest reduction efforts (around -80% between 2016 and 2040). The other countries have a slower reduction rate, in particular the rest of Asia, whose emissions decrease by around 45% between 2016 and 2040.
BP - Rapid Transition scenario	The power sector makes the greatest reduction efforts. Emissions from industry also decrease significantly, while those from transport only decrease slightly.	---	---
Low Energy Demand (LED) scenario	All sectors reach zero emissions by 2060. Negative emissions come from the LULUCF[a] sector - no use of BECCS.	Changes in all GHGs are described in the scenario database.	The countries of the South and the North reach carbon neutrality by 2060.

a. LULUCF: Land use, land-use change and forestry

STEP 7

IDENTIFYING THE SOLUTIONS DEPLOYED TO REDUCE GHG EMISSIONS AND THE ASSOCIATED TECHNOLOGIES

	Main low-carbon solutions mobilised (Mitigation solutions deployed illustrated by Figure 17, Figure 18, Figure 19, Figure 20)
IEA - SDS scenario	• Improving energy efficiency; • Developing renewable energies; • Developing nuclear, CCUS technologies; • Reducing methane emissions in oil and gas production (upstream).
Greenpeace - Advanced Energy Revolution scenario	• Improving energy efficiency; • Developing renewable energies, especially solar and wind; • Electrifying all sectors; • Decarbonising non-electric fuels through the use of hydrogen and biofuels for transport; • Decarbonising heat production, especially through the deployment of geothermal, the use of biomass and solar thermal collectors; • Choosing the non-use of CCUS and nuclear phase-out.
IRENA - REmap scenario	• Electrifying heat production and the transport sector; • Deploying renewable energies for electricity generation and for direct/end uses (solar, thermal, geothermal, biomass); • Improving energy efficiency (relatively less important than the first two solutions); • CCUS deployment not mentioned.
BP - Rapid Transition scenario	• Decarbonising the energy mix through the development of renewable energies, electrification and the deployment of CCUS technologies; • Energy efficiency gains, which do not offset the increase in demand for energy services: energy demand thus continues to increase until 2040.
Low Energy Demand (LED) scenario	• A drastic reduction in demand for energy through energy efficiency improvements in energy end use and the development of innovative energy services; • Electrifying energy uses; • Decarbonising and decentralising energy production through the development of renewable, variable and flexible energies; • Choosing the non-use of CCUS.

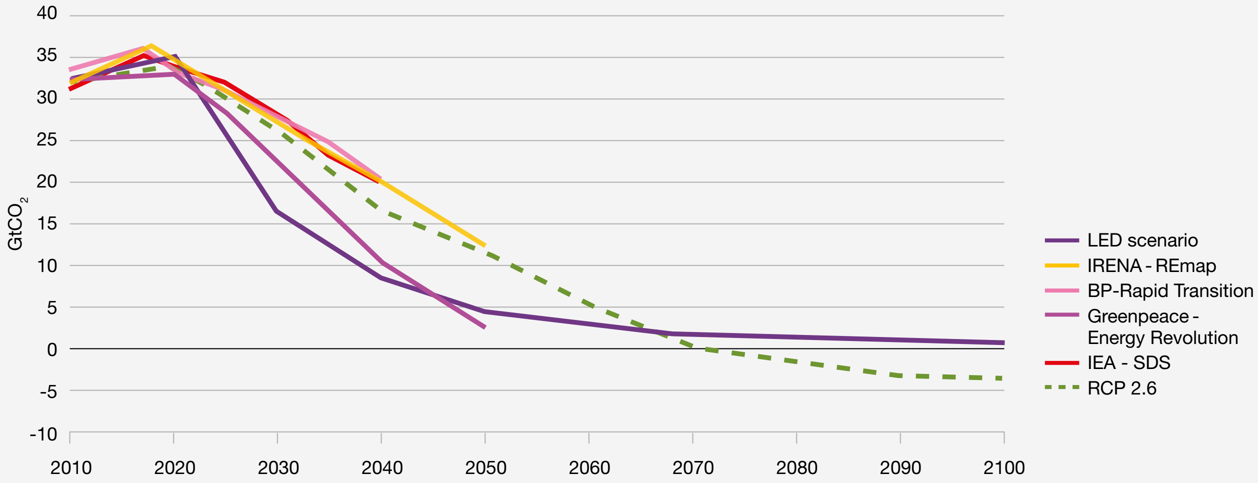
STEP 8

IDENTIFYING THE MACRO-ECONOMIC CONSEQUENCES OF THE TRANSITION

	Necessary investments	Impacts of the transition on GDP	Impacts of the transition on employment	Energy and electricity prices for end consumers	Fossil fuel prices
IEA - SDS scenario	**67,713 billion $** of cumulative investments in the energy system (energy supply and use) between 2018 and 2040 – 60,042 billion $ for the New Policies Scenario.	---	---	Electricity prices for end consumers are given for some regions. E.g. the electricity price increases from 85 $/MWh in 2017 to 120 $ MWh in 2040 in China, from around 130 to 165 $/MWh in the United States and from around 230 to 260 $/MWh in the EU.	Fossil fuel prices are endogenous to the scenario. Oil price: 74 $/barrel in 2025 and 64 $/barrel in 2040. Gas and coal prices vary according to the region. E.g. gas price in the EU: 7.7 $/MBtu in 2040; coal price in the EU: 66 $/tonne in 2040.
Greenpeace - Advanced Energy Revolution scenario	Over the period 2012-2050: **64,600 billion $** of cumulative investments in the power system (1,656 billion $/year on av.) **+16,730 billion $** of cumulative investments for heat production (429 billion $/year on av.).	---	**Positive impact on employment in the energy sector:** the scenario results in more jobs in the energy sector for each period in relation to the baseline scenario. For example, in 2030, there are 48 million jobs in the energy sector for the Advanced Revolution Scenario, compared to 28 million in the baseline scenario.	Prices for end consumers are not given, but electricity generation costs are given for the different parts of the world. For example, in the EU, the electricity generation cost increases until 2030 to reach almost 10 cts$/kWH, then decreases to around 8 cts$/kWh in 2050.	Fossil fuel prices are input assumptions. Oil price: 103.5 $/barrel in 2025 and 100 $/barrel in 2040. Gas and coal prices vary according to the region. E.g. gas price in Europe: 9.7 $/GJ in 2040; coal price for OECD countries: 3.3 $/GJ in 2040.
IRENA - REmap scenario	**110,000 billion $** of cumulative investments in the energy system for the period 2016-2050. In comparison, the cumulative investment requirements for the baseline scenario for the same period are 95,000 billion $.	Positive impact on GDP: the annual growth rate between 2019 and 2050 is 2.4% in the baseline scenario and **2.5%** in the REmap scenario (respectively 1.8% and **2%** when taking account of certain climate impacts).	• **Positive impact of the transition on employment in the energy sector:** new jobs linked to the transition far exceed jobs lost in the fossil fuel sector5. • Relatively insignificant impact of the transition on employment at the global economic level.	---	Fossil fuel prices are not given – it is simply noted that they are "taken from national studies or recognised sources (such as the IEA)".
BP - Rapid Transition scenario	---	---	---	---	---
Low Energy Demand (LED) scenario	Investments in energy supply are estimated at slightly more than **1,000 billion $ per year** between 2020 and 2050. (1,170 billion in 2020 and 1,053 billion in 2050).	---	---	---	---

a. Several IRENA studies assess the impacts of the transition on employment in the energy sector, including the study entitled *Perspectives for the energy transition: Investment needs for a low-carbon energy system*, IRENA and IEA, 2017

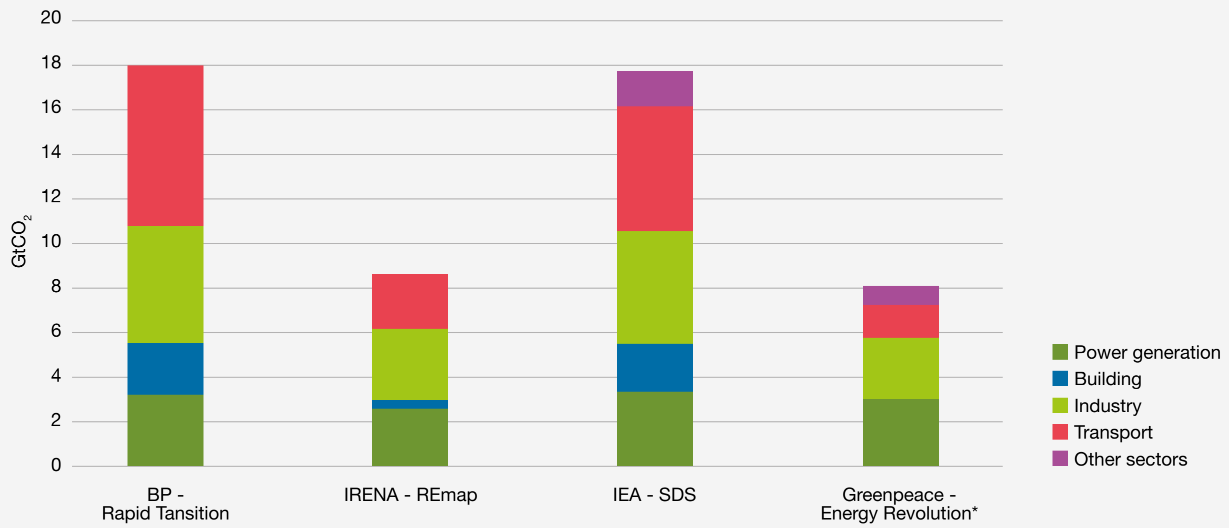
FIGURE 15. EMISSIONS TRAJECTORIES FOR CO_2 LINKED TO ENERGY AND INDUSTRIAL PROCESSES* ACCORDING TO DIFFERENT TRANSITION SCENARIOS



Source: I4CE, 2019.

* The scope of emissions in some of the scenarios selected does not include CO_2 emissions linked to industrial processes. To enable the visual comparison of emissions trajectories between the different scenarios, a yearly amount of 2.6 $GtCO_2$ was added to the emissions in scenarios that do not include industrial processes – SDS by IEA, Rapid Transition by BP, REmap by IRENA and Advanced Energy Revolution by Greenpeace. The amount of 2.6 $GtCO_2$ corresponds to current CO_2 emissions linked to industrial processes (Fischedick, 2014), and is compatible with information on these emissions taken from the SDS scenario by IEA (by visual reading) and REmap by IRENA (which gives the amount of cumulative emissions linked to industrial processes until 2050).

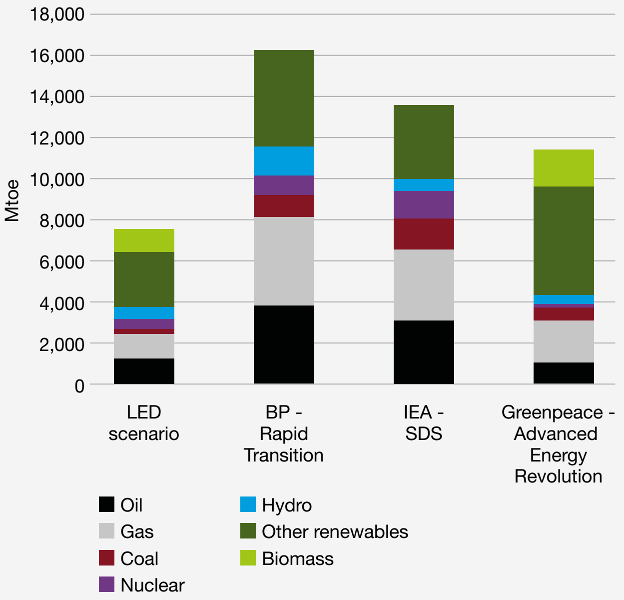
FIGURE 16. ENERGY-RELATED CO_2 EMISSIONS BY SECTOR IN 2040 ACCORDING TO DIFFERENT TRANSITION SCENARIOS



Source: I4CE, 2019.

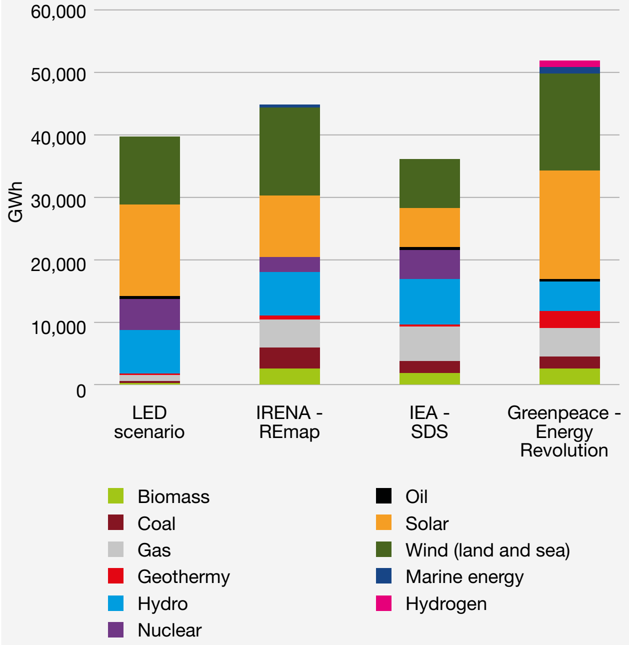
** Emissions from the “Building” sector in the Greenpeace Advanced Energy Revolution scenario are not nil in 2040; they are counted in “Other sectors”.*

FIGURE 17. PRIMARY ENERGY CONSUMPTION BY SOURCE IN 2040 ACCORDING TO DIFFERENT TRANSITION SCENARIOS



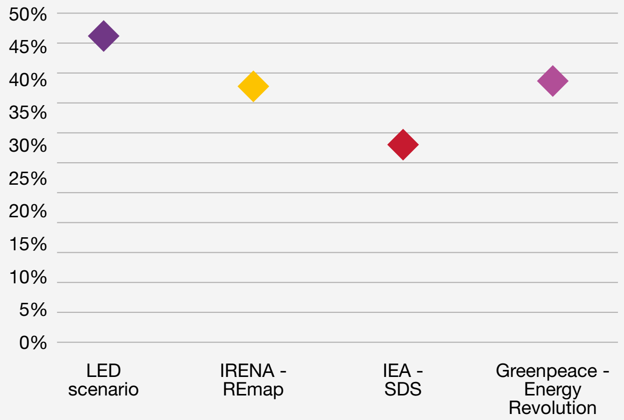
Source: I4CE, 2019.

FIGURE 18. ELECTRICITY GENERATION BY SOURCE IN 2040 ACCORDING TO DIFFERENT TRANSITION SCENARIOS



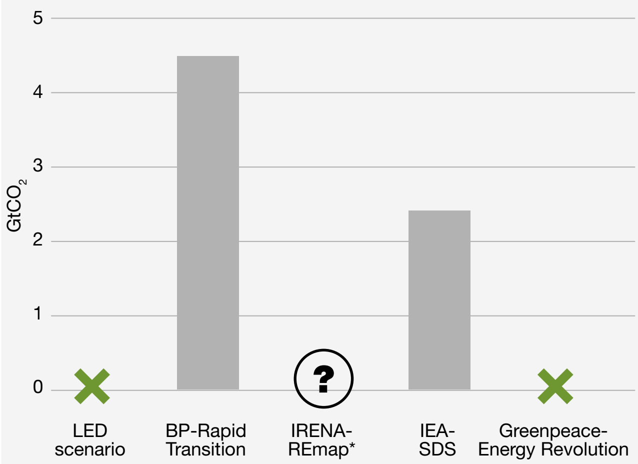
Source: I4CE, 2019.

FIGURE 19. SHARE OF ELECTRICITY IN FINAL ENERGY CONSUMPTION IN 2040 ACCORDING TO DIFFERENT TRANSITION SCENARIOS



Source: I4CE, 2019.

FIGURE 20. AMOUNT OF CO_2 CAPTURED BY CCUS IN 2040 ACCORDING TO DIFFERENT TRANSITION SCENARIOS



Source: I4CE, 2019.

* For the REmap scenario by IRENA, the amount of CCUS is not indicated. However, it is noted that CCUS technologies have been considered at the global level for three of the main emitting industries: steel, cement and chemicals/petrochemicals – but not for electricity production.

I4CE - Institute for Climate Economics 20-22 rue des Petits Hôtels, 75010 Paris
www.i4ce.org | contact@i4ce.org | @I4CE_

Création-réalisation : SophieBerlioz.fr