Course 2024–2025 in Sustainable Finance
Lecture 13. Transition Risk Modeling

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[1]The opinions expressed in this presentation are those of the authors and are not meant to represent the opinions or official positions of Amundi Asset Management.

Agenda

- Lecture 1: Introduction
- Lecture 2: ESG Scoring
- Lecture 3: Impact of ESG Investing on Asset Prices and Portfolio Returns
- Lecture 4: Sustainable Financial Products
- Lecture 5: Impact Investing
- Lecture 6: Biodiversity
- Lecture 7: Engagement & Voting Policy
- Lecture 8: Extra-financial Accounting
- Lecture 9: Awareness of Climate Change Impacts
- Lecture 10: The Ecosystem of Climate Change
- Lecture 11: Economic Models & Climate Change
- Lecture 12: Climate Risk Measures
- **Lecture 13: Transition Risk Modeling**
- Lecture 14: Climate Portfolio Construction
- Lecture 15: Physical Risk Modeling
- Lecture 16: Climate Stress Testing & Risk Management

Climate transition risk

Definition

- Transition risks arise from the sudden shift towards a low-carbon economy
- Such transitions could mean that some sectors of the economy face big shifts in asset values or higher costs of doing business

" It's not that policies stemming from deals like the Paris Climate Agreement are bad for our economy — in fact, the risk of delaying action altogether would be far worse. Rather, it's about the speed of transition to a greener economy — and how this affects certain sectors and financial stability" (Bank of England, 2021)

Climate transition risk

The carbon footprint approach assumes that the **climate-related market risk** of a company is measured by its **current carbon intensity**

...But the **market perception** of the climate change may be different

Carbon price

Two main pricing systems:

1. Carbon tax
2. Emissions trading system (ETS)

Underlying idea

- A high carbon tax impacts the creditworthiness of corporates
- This impact is different from one issuer to another one
- Identifying for each company the carbon price that would lead the default probability in the Merton model to exceed a certain threshold

Existing carbon pricing solutions

Climate policy

- Carbon pricing: main tool to implement public policies to reduce CO_2 emissions

  "*Carbon pricing is an instrument that captures the external costs of greenhouse gas (GHG) emissions — the costs of emissions that the public pays for, such as damage to crops, health care costs from heat waves and droughts, and loss of property from flooding and sea level rise — and ties them to their sources through a price, usually in the form of a price on the carbon dioxide emitted.*" *(World Bank, 2021)*

- Can take several forms: carbon tax, emissions trading system, carbon credit
- Underlying idea: the biggest GHG emitters must pay higher tax or face higher costs
- Goal: transform deeply their activities ⇒ lower their emissions

Economic theory of negative externalities

Prices vs. Quantities

- Weitzman (1974)
- Laffont (1977)
- Pizer (2002)
- McKibbin and Wilcoxen (2002)
- Hepburn (2006)
- Tang *et al.* (2018)

Prices vs. Quantities

"Choosing appropriate policy instruments is an important part of successful regulation. Once objectives are agreed and suitable targets adopted, policy-makers can employ command-and-control regulation and/or economic instruments, and choose between fixing a price or a quantity." (Hepburn, 2006, page 226).

Optimal taxation

Economic theory of quotas

Uncertainty

Irreversibility

Cost-benefit analysis versus option theory

Two forms of carbon pricing

External carbon pricing

- Managed by governments
- Examples: carbon tax, emission trading system (ETS)
- Reflect the price of a tonne of CO_2e emitted.

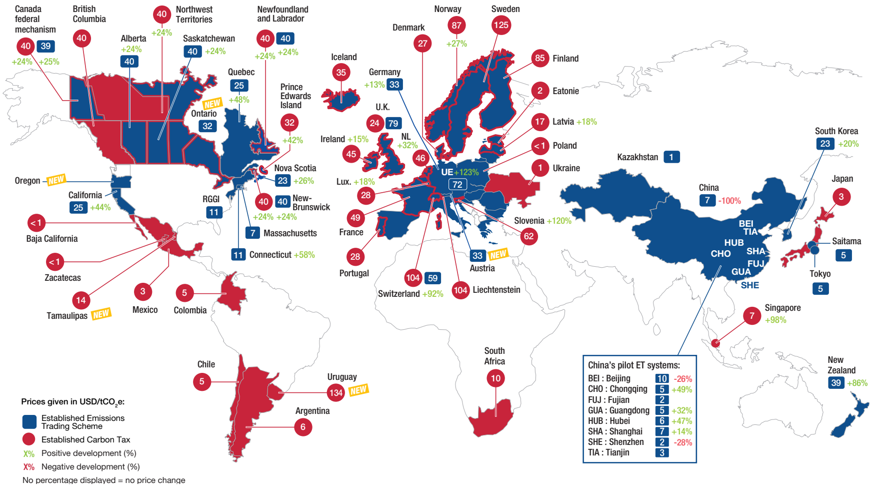
Internal carbon pricing

- Managed by corporates
- Examples: internal carbon fee, shadow price, implicit price

There are 68 explicit carbon pricing mechanisms as of 1st August 2022, with the following breakdown: 32 emission trading systems and 36 carbon taxes

Two forms of carbon pricing

Figure 1: Map of explicit carbon prices around the world in 2022



Social cost of carbon

- "Present value of the economic impact of an additional tonne of CO_2 emitted"
- Introduced by Nordhaus in 1991:

$$\mathrm{SCC}(t) = -\frac{\dfrac{\partial W}{\partial \mathcal{CE}(t)}}{\dfrac{\partial W}{\partial C(t)}} = -\frac{\partial C(t)}{\partial \mathcal{CE}(t)}$$

where W denotes the social welfare function, $\mathcal{CE}(t)$ is the total GHG emissions at time t and $C(t)$ is the consumption at time t

- The term $\dfrac{\partial W}{\partial \mathcal{CE}(t)} \leq 0$ is the marginal social welfare with respect to GHG emissions, while $\dfrac{\partial W}{\partial C(t)} \geq 0$ is the marginal utility of consumption

Social cost of carbon

Figure 2: Histogram of the 150 000 US Government SCC estimates for 2020 with a 3% discount rate

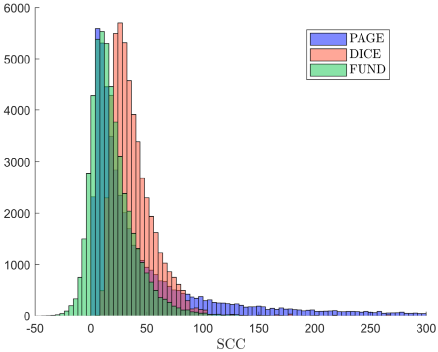
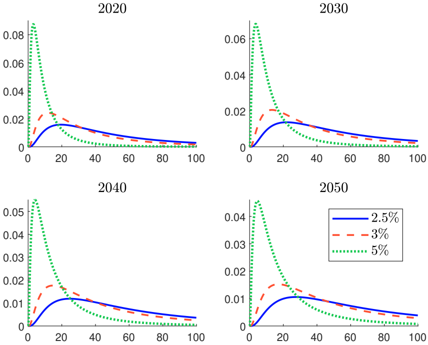
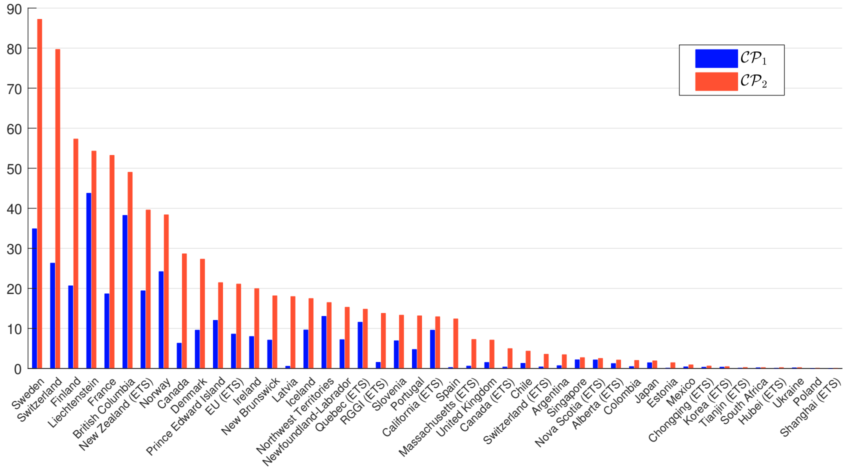


Figure 3: Probability distribution of the SCC (log-normal)

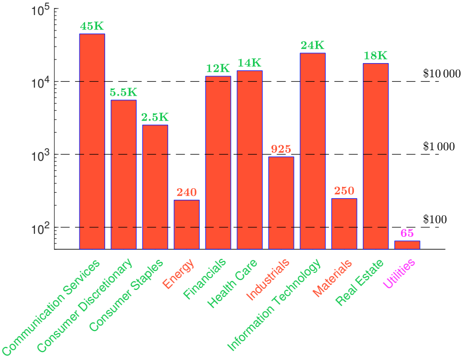


Implied carbon prices



Carbon tax and direct emissions

Figure 4: Break-even carbon tax in $\$/tCO_2$ (MSCI World index, December 2021)



- We assume a flat carbon tax: $\mathit{Cost} = \mathcal{CT} \cdot \mathcal{CE}_1$
- Utilities, Energy, Materials and Industrials are the most impacted sectors $\Rightarrow$ Cost over Dividend ratio of 210.64, 81.64, 94.05 and 30.45
- Communication Services, Information Technology, Real Estate and Health Care are less impacted $\Rightarrow$ Cost over Dividend ratio of 0.93, 1.42, 0.99 and 1.80

Carbon tax: a high heterogeneity between and within sectors

Figure 5: Boxplot of the *Cost*/*Dividend* ratio in % (MSCI World index, December 2021, $\mathcal{CT} = \$100/\mathrm{tCO_2}$)

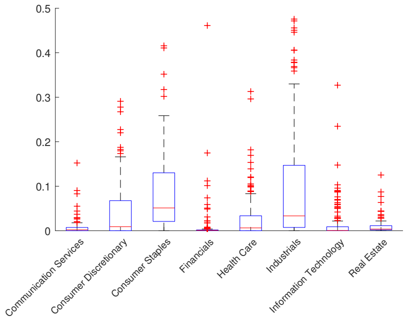
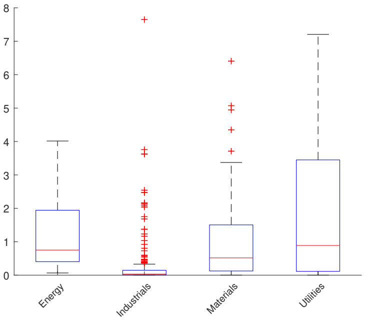


Figure 6: Boxplot of the *Cost*/*Dividend* ratio in % (MSCI World index, December 2021, $\mathcal{CT} = \$100/\mathrm{tCO_2}$)



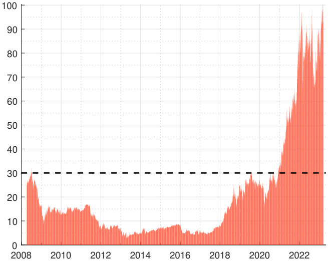
Emissions trading system

Emission Trading System (ETS)

Definition

Market where corporates and countries can trade carbon emissions to meet their targets. A global amount of emissions that can be traded by the different entities.

Figure 7: EU ETS carbon allowance price



- Cap-and-trade system
- Remained for a long time below €30/tCO_2e, sharp decline after the Global Financial Crisis from €30 in 2008 to a mere €2.75 in April 2013
- Carbon price went from €34 in January 2021 to nearly €100 in February 2023

Probability distribution of the EU ETS carbon price

Figure 8: Volatility of carbon price

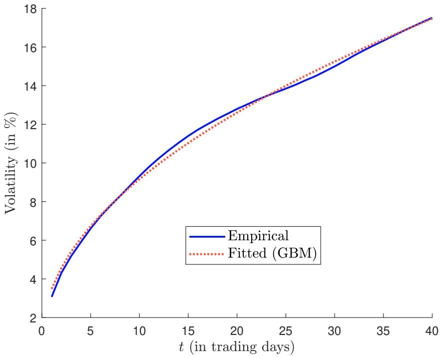
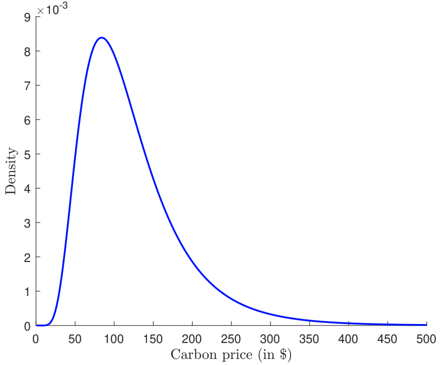


Figure 9: PDF of the carbon price

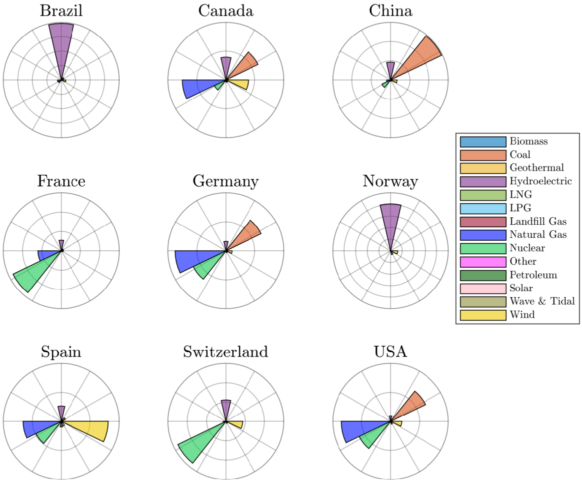


Carbon pricing

Stranded assets

Bottom up energy mix$^{(*)}$ (in %)

This figure presents the energy generation breakdown for some countries. We can distinguish countries that rely on hydroelectric power (Brazil, Norway), nuclear (France, Switzerland) and mixed solutions (Canada, Germany, Spain, USA)



$^{(*)}$ Each grid circle represents 20% of energy generation. The scale of the radar chart is then 40% for Canada, Germany, Spain and USA, 60% for China, France and Switzerland, 80% for Brazil and 100% for Norway

Financing side of the net-zero transition

How to achieve net zero emissions

The main transformation involves the power sector in two directions:

1. Massive electrification of the world economy
2. Greening electricity to achieve clean power generation

Table 1: The 2050 net-zero scenarios

2020		
Production	Energy Intensity	Carbon Emissions
30 000 TWh	**500** g/kWh	**15** $GtCO_2e$
2050		
Production	Energy Intensity	Carbon Emissions
100 000 TWh	**20** g/kWh	**2** $GtCO_2e$

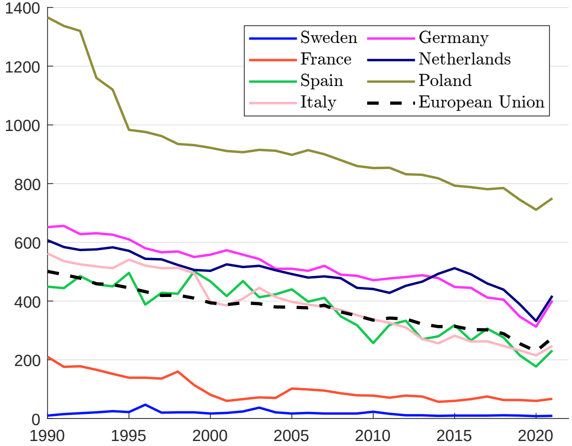
How to achieve net zero emissions

Table 2: Emission factor in gCO_2e/kWh of electricity generation in the world

Region	$\mathcal{EF}$	Country	$\mathcal{EF}$	Country	$\mathcal{EF}$	Country	$\mathcal{EF}$
Africa	484	Australia	531	Germany	354	Portugal	183
Asia	539	Canada	128	India	637	Russia	360
Europe	280	China	544	Iran	492	Spain	169
North America	352	Costa Rica	33	Italy	226	Switzerland	47
South America	204	Cuba	575	Japan	479	United Kingdom	270
World	442	France	58	Norway	26	United States	380

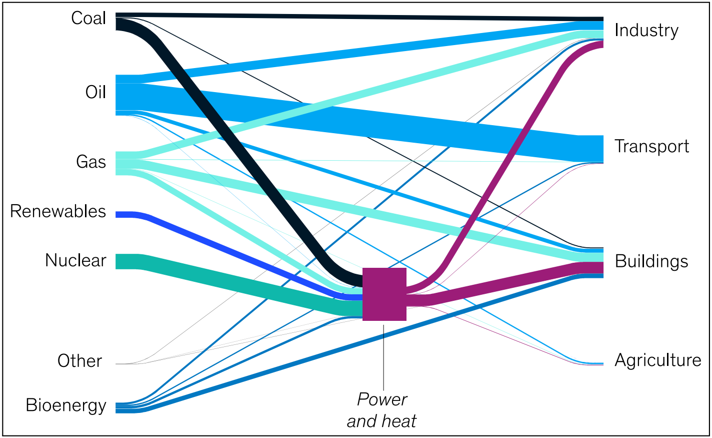
How to achieve net zero emissions

Figure 10: Emission factor in gCO_2e/kWh of electricity generation (European Union, 1990-2022)



Transforming the global value chain into a net zero economy

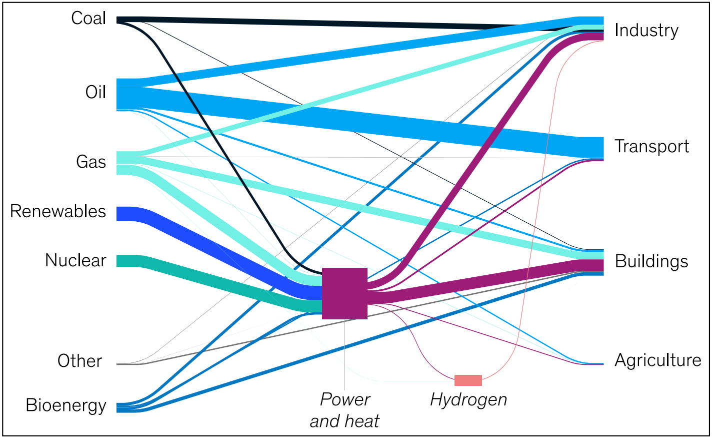
Figure 11: Global value chain in 2017



Source: McKinsey (2023, Exhibit 6B, page 12).

Transforming the global value chain into a net zero economy

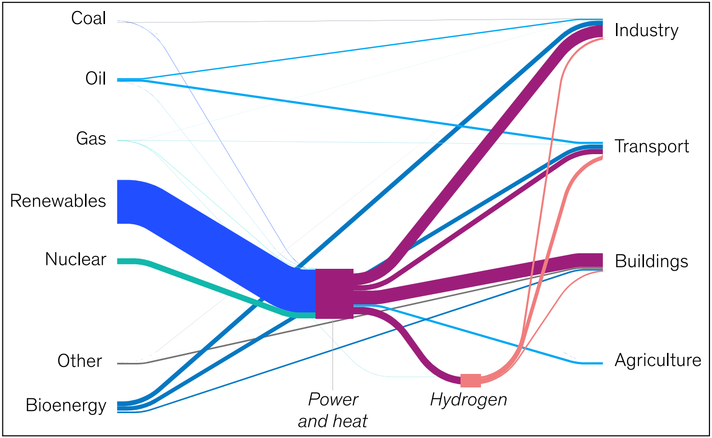
Figure 12: Global value chain in 2030



Source: McKinsey (2023, Exhibit 6B, page 12).

Transforming the global value chain into a net zero economy

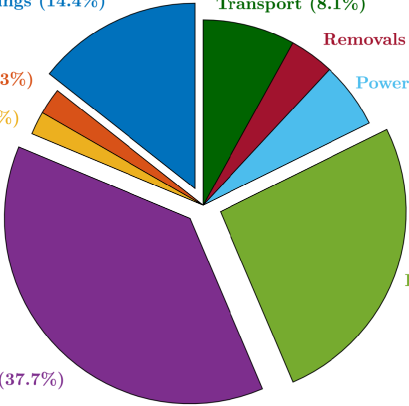
Figure 13: Global value chain in 2050



Source: McKinsey (2023, Exhibit 6B, page 12).

Funding requirements

Figure 14: Net zero capital investments



Source: Energy Transitions Commission (2023a) & Ben Slimane *et al.* (2023b).

Funding requirements

Table 3: Importance of GICS sectors in net zero investing

Communication Services
Consumer Discretionary
Consumer Staples
Energy
Financials
Health Care
Industrials
Information Technology
Materials
Real Estate
Utilities

We obtain the following five clusters from the most important to the least important:

1. Utilities;
2. Materials, Industrials;
3. Consumer Discretionary, Real Estate;
4. Energy, Information Technology, Consumer Staples, Health Care;
5. Financials, Consumer Services.

Material and resource requirements

Table 4: Mineral requirements for clean energy technologies

	Aluminium	Chromium	Copper	Cobalt	Graphite	Lithium	Neodymium
Bioenergy	◐	○	●	○	○	○	○
CSP	●	●	◐	○	○	○	○
Electricity Networks	●	○	●	○	○	○	○
EVs and Battery storage	●	○	●	●	●	●	●
Geothermal	○	●	○	○	○	○	○
Hydrogen	◐	○	○	○	○	○	○
Hydropower	◐	◐	◐	○	○	○	○
Nuclear	○	◐	◐	○	○	○	◐
Solar PV	●	○	●	○	○	○	○
Wind	◐	◐	●	○	○	○	●

Source: IEA (2022, page 45).

Material and resource requirements

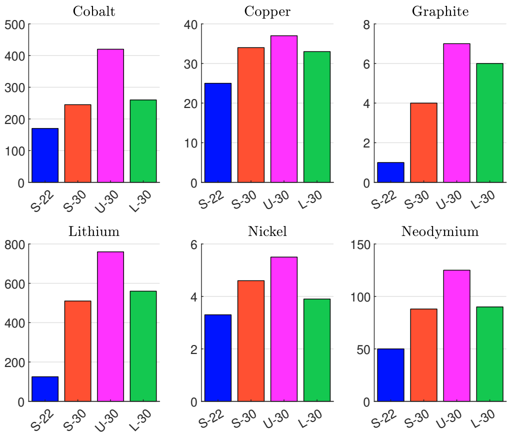
Table 5: Mineral requirements for clean energy technologies

	Nickel	Platinum	Polysilicon	REEs	Silver	Steel	Uranium	Zinc
Bioenergy	○	○	○	○	○	○	○	◍
CSP	◍	○	○	○	○	○	○	◍
Electricity Networks	○	○	○	○	○	●	○	○
EVs and Battery storage	●	○	○	●	○	○	○	○
Geothermal	●	○	○	○	○	○	○	○
Hydrogen	●	●	○	◍	○	●	○	○
Hydropower	○	○	○	○	○	●	○	◍
Nuclear	◍	○	○	○	○	●	●	○
Solar PV	○	○	●	○	●	●	○	○
Wind	◍	○	○	●	○	●	○	●

Source: IEA (2022, page 45).

Material and resource requirements

Figure 15: Demand and primary supply in 2030



Source: Energy Transitions Commission (2023a).

Sector analysis

Total investment: **3.5 trillion per year to 2050**

Sector analysis

Power ($2 400 bn)

- Total electricity supply from around 30 000 TWh today to over 100 000 TWh by mid-century
- Extension of transmission and distribution networks from about 70 million km to up to 200 million km
- Green hydrogen production of 500-800 Mt per year

Buildings ($500 bn)

- Need to retrofit older buildings and create new carbon-efficient buildings
- $500 bn per year invested in the buildings sector: incorporate new green technologies ($230 bn), purchase renewable heat ($130 bn) and install new heat pumps ($150 bn)

Sector analysis

Mobility ($280 bn)

- The largest part of the transition from ICE (internal combustion engines) to EVs will require $130 bn per year to develop charging and refuelling facilities
- $70 bn will be spent on sustainable aircraft manufacturing facilities and aircraft batteries
- $40 bn will be spent on greening the shipping system through new infrastructure, vessels and investments

Sustainable agriculture and land use requirements ($50 bn)

- The demand for wind and solar farms is far greater than the previous demand based on the fossil fuel system, but still far less than the demand for agriculture
- Agriculture is the largest driver of deforestation

Sector analysis

Hydrogen ($80 bn)

- $80 bn investment will be allocated to the production and distribution of hydrogen
- $40 bn will be used to produce green and blue hydrogen and to recycle grey hydrogen
- $40 bn will help build pipelines, refuelling stations, exchange terminals and storage capacity

Industry ($70 bn)

- $10 bn will be used to decarbonise steel
- $10 bn for cement plants
- $40 bn to fully develop and integrate CCS and other decarbonisation technologies
- $10 bn to deploy low-carbon technologies in smelters and refineries

Sector analysis

Waste management and circular economy ($135 bn)

- Waste is generated at every stage of the transition, from food waste from agriculture to waste from solar panels, wind farms or even mining
- The energy transition will generate up to 13 billion tonnes of waste from all materials by 2050

Water management ($25 bn)

- Global water consumption will be 4 000 billion m^3 per year in 2050, of which 70% is used for agriculture (2 800 billion m^3), 58 billion m^3 for clean energy production and 37 billion m^3 for fossil fuels
- For clean energy production, water is used for nuclear power generation (14 billion m^3 per year), hydrogen production by electrolysis (11 billion m^3 per year), carbon capture (19–29 billion m^3 per year) and cleaning solar panels
- Global energy use in the water sector expected to double by 2040

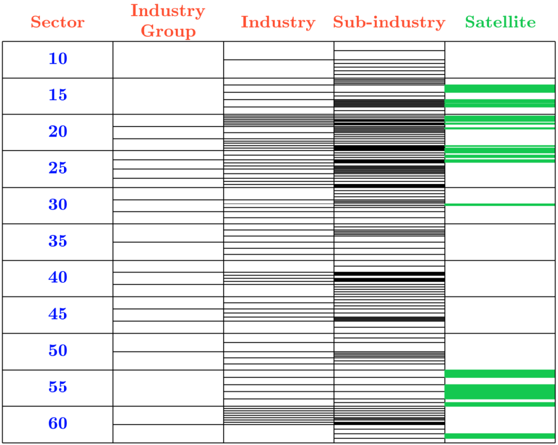
Narrow definition of the satellite investment portfolio

Table 6: Main sub-industries of the net zero satellite portfolio (GICS level 4)

15102010	Construction Materials	Materials	Materials
15104010	Aluminum		
15104020	Diversified Metals & Mining		
15104025	Copper		
15104040	Precious Metals & Minerals		
15104045	Silver		
15104050	Steel		
20102010	Building Products	Capital Goods	Industrials
20103010	Construction & Engineering		
20104010	Electrical Components & Equipment		
20104020	Heavy Electrical Equipment		
20106010	Construction Machinery & Heavy Transportation Eqpt.		
20106015	Agricultural & Farm Machinery		
20201050	Environmental & Facilities Services	Commercial & Professional Services	
20304010	Rail Transportation	Transportation	
20305010	Airport Services		
20305020	Highways & Railtracks		
20305030	Marine Ports & Services		
25101010	Automotive Parts & Equipment	Automobiles & Components	Consumer Discretionary
25102010	Automobile Manufacturers		
25201010	Consumer Electronics	Consumer Durables & Apparel	
25201030	Homebuilding		
25201040	Household Appliances		
30202010	Agricultural Products	Services Food, Beverage & Tobacco	Consumer Staples
55101010	Electric Utilities	Utilities	Utilities
55103010	Multi-Utilities		
55104010	Water Utilities		
55105020	Renewable Electricity		
60201030	Real Estate Development	Real Estate Management & Development	Real Estate

Narrow definition of the satellite investment portfolio

Figure 16: Narrow specification of the satellite investment universe



Tracking net zero progress

Table 7: What's on track (energy system overview)

Energy Efficiency	🟡
Behavioural Changes	🔴
Electrification	🟡
Renewables	🟡
Bioenergy	🟡
Hydrogen	🟡
Carbon Capture, Utilisation and Storage	🔴
Innovation	🟡
International Collaboration	🟡
Digitalisation	🟡

🟢 on track, 🟡 more efforts needed, 🔴 not on track

Source: IEA (2023).

Tracking net zero progress

Table 8: What's on track (sector analysis)

Transversal Technologies & Infrastructure	Yellow	**Electricity**	Yellow
CO_2 Transport and Storage	Red	Coal	Red
CO_2 Capture and Utilisation	Yellow	Natural Gas	Yellow
Bioenergy with Carbon Capture and Storage	Red	Solar PV	Green
Direct Air Capture	Yellow	Wind	Yellow
Electrolysers	Yellow	Hydroelectricity	Yellow
District Heating	Red	Demand Response	Yellow
Data Centres and Transmission Networks	Yellow	Nuclear Power	Yellow
Transport	Red	Grid-scale Storage	Yellow
Cars and Vans	Yellow	Smart Grids	Yellow
Trucks and Buses	Red	**Energy**	Red
Rail	Yellow	Oil & Natural Gas Supply	Red
Aviation	Red	Methane Abatement	Red
International Shipping	Red	Gas Flaring	Red
Electric Vehicles	Green	Biofuels	Red
Industry	Red	**Buildings**	Yellow
Steel	Red	Heating	Yellow
Chemicals	Red	Space Cooling	Yellow
Cement	Red	Lighting	Green
Aluminium	Red	Appliances & Equipment	Yellow
Paper	Red	Building Envelopes	Red
Light Industry	Yellow	Heat Pumps	Yellow

Public vs. private investments

Figure 17: Public investment – relative difference in % compared with the baseline scenario

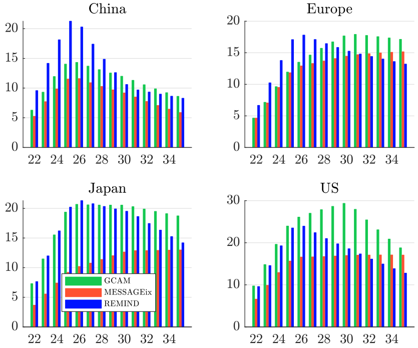
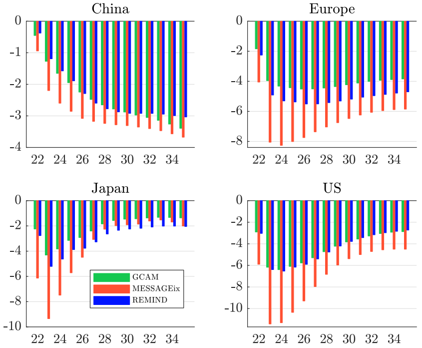


Figure 18: Private investment – relative difference in % compared with the baseline scenario



Source: NGFS (2022) & https://data.ene.iiasa.ac.at/ngfs.

Public vs. private investments

What are the narratives

- Net zero emissions scenario ⇒ Huge cost
- This cost mainly concerns the Utilities sector

- Utilities ⇒ Huge capex ⇒ ROE ↘
- Private investors are reluctant to finance the utilities sector
- Private investment ↘

- A strong increase of public investment
- Debt ↗ ⇒ Interest rates ↗
- Investors prefer to invest in sovereign bonds than financing directly net zero

Vase communication between public investment and private investment