Untying the Knot: Explorations to Meet Climate and Sustainability Goals

Detlef van Vuuren
International promises to do better...

Aichi targets: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society and reduce the direct pressures on biodiversity and promote sustainable use...

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity.
International promises to do better...

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Media Release: Nature’s Dangerous Decline ‘Unprecedented’; Species Extinction Rates ‘Accelerating’

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity.
International promises to do better...

The universal agreement’s main aim is to keep a global temperature rise this century well below 2 degrees Celsius and to drive efforts to limit the temperature increase even further to 1.5 degrees Celsius above pre-industrial levels.

Aichi targets: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society and reduce the direct pressures on biodiversity and promote sustainable use...

Our common quest should be: What is needed to achieve the goals; how can we bend the trend?

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International promises to do better...

**Aichi targets:** Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society and reduce the direct pressures on biodiversity and promote sustainable use...

**How will the future evolve?**

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to **end poverty, protect the planet**, and ensure that by 2030 all people enjoy peace and prosperity.
How will the future evolve?

Population
Socio-economic development
Technology
Political change
Policy
Demand for food, energy and water
Environmental problems
Climate change
Scarcity

Different scales
Different time periods
Uncertainty
How will the future evolve?
Sustainable development goals (SDGs)
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Human development and equity

1 No poverty
2 Zero hunger
3 Good health and well-being
4 Quality education
5 Gender equality
6 Clean water and sanitation
7 Affordable and clean energy
8 Decent work and economic growth
9 Industry, innovation and infrastructure
10 Reduced inequalities
11 Sustainable cities and communities
12 Responsible consumption and production
13 Climate action

Efficient and sustainable resource use

14 Life below water
15 Life on land
16 Peace and justice, strong institutions
17 Partnerships for the goals

Protecting natural environment

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Describe evolution of future systems

Earth system
- Ecosystem dynamics
- Climate change
- Pollution
- Biogeochemical cycles

Human system
- Population
- Economy
- Technology

Resource Drivers use
- Energy
- Agriculture

Interaction
- Emissions
- Land use
- Impacts

Beliefs, culture
- Rules, laws, behaviour
- Physical entities
Describe evolution of future systems

Available tools

- Storylines
- Scenarios
- Models

Beliefs, culture
Rules, laws, behaviour
Physical entities
Model-based scenarios

Scenarios:
- Combination of narratives and modelling
- Modelling where there is enough knowledge to define quantitative relationships
- Narratives where there is need for complexity and flexibility
Content of rest of presentation

• Look into area of climate research to see how scenarios can be used
• See how this can be further expanded
• Draw some conclusions
Climate
Model-based scenarios

Shared Socio-economic Pathways

Climate

Forcing level (W/m²)

SSP1  SSP2  SSP3  SSP4  SSP5

Socio-economic conditions
Model-based scenarios

- SSP1
- SSP2
- SSP3
- SSP4
- SSP5

Challenge to adaptation vs Challenge to mitigation
Shared Socio-economic Pathways: 5 possible stories about the future

**SSP1: Green growth**
- Global cooperation
- Rapid technology development
- Strong env. policy
- Low population growth
- Low inequity
- Focus on renewables and efficiency
- Dietary shifts
- Forest protection

**SSP2: Middle of the Road**
- Markets first
- Clash of civilisations

**SSP3: Regional rivalry**
- Competition among regions
- Low technology development
- Environment and social goals not a priority
- Focus on domestic resources
- High population growth
- Slow economic growth dev. countries

**SSP4: Inequality**
- Inequality across and within regions
- Low technology development
- Environment priority for those that can afford
- Limited trade

**SSP5: Fossil fuel-ed development**
- Rapid growth, free trade
- High technology development
- Environment and social goals not a priority: adaptive, technology-fix
- Focus on economic growth

- UN world
- Have’s and have not’s

- Clash of civilisations
Human system

Drivers
- Population
- Economy
- Technology

Resource use
- Energy
- Agriculture

Interaction
- Emissions
- Land use
- Impacts

Earth system

Earth system dynamics
- Climate change
- Pollution

Biogeochemical cycles

Population
- SSP3
- SSP2, SSP4
- SSP1, SSP5

Income
- SSP5
- SSP2
- SSP4
- SSP3

SSP1: Sustainable development
SSP2: Middle of the road
SSP3: Increasing competition
SSP4: Divided world
SSP5: Rapid growth
As a result, in all 5 stories without stringent climate policy:
- further increase in global energy use
- Fossil fuels continue to be important
- Thus increasing greenhouse gas emissions
Human system

Drivers
- Population
- Economy
- Technology

Resource use
- Energy
- Agriculture

Interaction
- Emissions
- Land use

Impact

Earth system
- Ecosystem dynamics
- Climate change
- Pollution
- Biogeochemical cycles

Interaction demand / supply
Allocation based on prices and preferences
Detailed representation of processes (technology development, depletion) and sectors (e.g., transport)
Cumulative CO$_2$ emissions (GtCO$_2$)

Temperature increase (°C)

Global CO$_2$ emissions

Emissions $\rightarrow$ temperature

Cumulative CO$_2$ emissions (GtCO$_2$)
Global CO₂ emissions

4000-5000 GtCO₂

Temperature increase (°C)

Cumulative CO₂ emissions (GtCO₂)

Emissions → temperature
Global CO₂ emissions

Emissions → temperature

- Annual emissions (GtCO₂)
- Cumulative CO₂ emissions (GtCO₂)
- Temperature increase (°C)

- 1980
- 2000
- 2020
- 2040
- 2060
- 2080
- 2100

- Gt CO₂-eq.

- ~400
- ~1000
- ~400
- pbl.nl

- 0
- 20
- 40
- 60
- 80

- 0
- 1
- 2
- 3
- 4
- 5

- 1980
- 2000
- 2020
- 2040
- 2060
- 2080
- 2100
Global CO$_2$ emissions

- 650 GtCO$_2$ in existing infrastructure;
- 200 GtCO$_2$ in plans

Emissions $\rightarrow$ temperature

- $\sim$1000
- $\sim$400
Negative emissions:
- Reforestation
- Bio-energy with CCS
- Direct air capture
- Nature-based solution (e.g. soil carbon)
- ...

Could help, but
- Temporary overshoot temperature target
- Possible negative impacts on land use
- Limit potential
Emerging consensus: net zero ~2050

- Distribution within time
- Non-CO₂

Net zero target is less certain – but sets a clear point at the horizon

Flexibility in pathways

Global CO₂ emissions

Emerging consensus: net zero ~2050
Current policy

Global emissions greenhouse gas

- Non-CO₂
- Process emissions
- Buildings
- Industry
- Transport
- Energy sector
- Land use change
- Negative emissions
Current policy

Global emissions greenhouse gas

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Current policy

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Global energy use

- Renewables
- Bio-energy
- Fossil with CCS
- Fossil without CCS
- Nuclear
Current policy

Global emissions greenhouse gas
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Global emissions greenhouse gas

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12 December 2021
Global emissions greenhouse gas

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- Process emissions
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Global energy use

- Renewables
- Bio-energy
- Fossil with CCS
- Fossil without CCS
- Nuclear
CO₂ removal

Energy system

- Renewable energy
- Systeem integration + CCS, bio, nuclear
- H₂, CCS, bio for specific applications

Industry

- Electrifications
- Limit demand
- CDR (development)

Mobility

- Diet change
- Reforestation

Buildings

Food systems

Land use

Diet change

Renewable energy

Efficiency

Lifestyle change

Non-CO₂
Going beyond climate
Global material extraction

- Fresh water
- Non-metallic minerals
- Metal ores
- Fossil fuels
- Biomass

Resource use related to the way:
- We transport
- We eat
- We live

Infrastructure, energy and goods

Source: IRP – Global Resource Outlook 2019
Source: Van Vuuren et al. (2019). Nature Sustainability
Source: Van Vuuren et al. (2019). Nature Sustainability
Implications of increasing material demand

Implications of energy infrastructure

Industry

In-use

Waste

Energy

Emissions
Deetman et al, 2018

Pauliuk et al (2021), Nature Communications. August 24

Implications of energy transition

Prevent biodiversity loss

Prevent water scarcity

Implications of increasing circular economy
### Scenarios

<table>
<thead>
<tr>
<th>Measures</th>
<th>WATER</th>
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b) natural land share

Scenario
- WATER
- CLIMATE
- LAND
- TOTAL
- FOOD

Region
- JKO
- CSA
- EUR
- SAS
- NAM
- SEA
- MEN
- SSA
- RICA
- WLD
- CHN

Doelman et al., in review
### Scenarios

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### Model Comparison

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<tr>
<td>Water Withdrawal Irrigation</td>
<td>-26%</td>
<td>+10%</td>
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<tr>
<td>Natural Land Area</td>
<td>0%</td>
<td>+2%</td>
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<tr>
<td>Nitrogen Surplus Agriculture</td>
<td>-27%</td>
<td>-27%</td>
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<td>Food Price</td>
<td>+1%</td>
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<tr>
<td>AFOLU Emissions</td>
<td>-3%</td>
<td>-14%</td>
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### Defining a Sustainable Development Target Space for 2030 and 2050

Detlef P. van Vuuren*1,2, Caroline Zimm3, Sebastian Busch4, Elmar Kriegler5, Julia Leininger6, Dirk Messner7, Nebojsa Nakicenovic3, Johan Rockstrom5,8, Keywan Riahi9,10, Frank Sperling3,10, Valentina Bosetti11, Sarah Cornell12, Owen Gaffney12, Paul L. Lucas1, Alexander Popp1, Constantin Ruhe6,12, Armin von Schiller6, Jörn O. Schmidt13,14, Bjoern Soergel1

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#### Indicators

| SDG1 | SDG2 | SDG3 | SDG4 | SDG5 | SDG6 | SDG7 | SDG8 | ...
|------|------|------|------|------|------|------|------|------|

https://eartharxiv.org/repository/view/2386/
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...
Untying the knot
• Lot of experience on single issue scenario work regarding solutions...
• But knowledge on the connections is still developing
• Common knowledge base
  • Linking different types of research
  • Use of common scenarios
  • Learning across scales
  • Social science / natural science
  • Different research foci (e.g. CE, nexus, climate, biodiversity)