Bridging the gap between NDCs & Paris Ambition: equitable finance for pathways well below 2°C
(Work in progress, please don’t cite)

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Research Context

• We normally focus on least cost optimised solutions for a future decarbonised energy system.

• How do we account for equity and fairness for deep decarbonisation of the global energy system in the post Paris Agreement era?

• In this paper we focus on a least cost energy system solution and capital transfers based on equitable effort sharing rules to quantify the range of finance required under the Paris agreement, and assess whether $100bn/yr is appropriate.
Post Paris Policy Context – COP21

Highlight figures.

• CP21, Article 2.1.a Holding the increase in the global average temperature to **well below 2°C** above pre-industrial levels and **pursuing efforts to limit temperature increase to 1.5 °C** would significantly reduce risks and impacts of climate change.

• Article 4.2 Each party shall prepare, communicate and maintain successive **nationally determined contributions** that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

• Article 4.3 Each Party’s successive **nationally determined contribution** will represent a progression beyond the party’s then current nationally determined contributions and **reflect its highest possible ambition**, reflecting its common but differentiated responsibilities and respective capabilities in the light of different national circumstances.
• Also decides that, in accordance with Article 9, paragraph 3, of the agreement developed countries intend to continue their existing collective mobilisation goal through 2025 in the context of meaningful mitigation actions and transparency on the implementation: prior to 2025 the conference of the parties serving as the meeting of the parties to the Paris agreement shall set a new collective quantified goal from a floor of USD 100 billion per year, taking into account the needs and priorities of developing countries.
Post Paris Policy Context – COP21
Carbon Budgets & Nationally Determined Contributions

• AR5 carbon budget for the total global cumulative emissions since 2011 that are consistent with a global average temperature rise of **1.5°C above pre industrial levels** with 50% probability is **550 GtCO_2**.

• Considering the aggregate effect of INDCs, global cumulative CO_2 emissions are expected to equal 97% by 2025 and 134% by 2030 of the cumulative emissions consistent with achieving a temperature increase of less than 1.5°C.

• INDCs are estimated to result in global annual ~**52 GtCO_2e/yr** in 2030
  • Not on a 2 °C least cost consistent path
INDC action is not fast enough
UNFCCC INDC Synthesis Report
Cumulative CO$_2$ vs Linear T°C
IPCC AR5

(b) Warming versus cumulative CO$_2$ emissions

Total human-induced warming
observed 2000s

Cumulative anthropogenic CO$_2$ emissions from 1870 (GtCO$_2$)

0 1000 2000 3000 4000 5000 6000 7000 8000 9000
0 1 2 3 4 5

baselines

430–480
480–530
530–580
580–720
720–1000
Temperature Anomaly

GISTEMP Anomaly (including seasonal cycle)

Seasonal cycle from MERRA2. Figure: NASA GISS/Gavin Schmidt

Predicting the 2016 GISTEMP LOTI mean anomaly

Estimate based on Jan-Sep
Baseline (1860-1899)
Global Carbon Clock

1.5°C - 2°C
550-1000 GtCO2 left

- 1750: 175 years
- 1925: 34 years
- 1959: 16 years
- 1975: 13 years
- 1988: 10 years
- 2007: 9 years
- 2015: 8 years
- 2015: 11 years
- 2021: 9 years
- +1°C: 11 years
- +1.5°C: 9 years

#COP21
Population proportion trends

World Population (UN 2014)

- Western Europe
- USA
- South Korea
- Other Developing Asia
- Mexico
- Middle East
- Japan
- India
- Former Soviet Union
- Eastern Europe
- Central & South America
Research Question?

• How do we account for equity and fairness for deep decarbonisation of the global energy system in the post Paris Agreement era?

• In what circumstances is the finance in the Paris agreement, $100bn/year, appropriate?
ETSAP-TIAM global model

- Linear programming bottom-up energy system model of IEA-ETSAP
- Integrated model of the entire energy system
- Prospective analysis on medium to long term horizon (2100)
  - Demand driven by exogenous energy service demands
  - OECD Env Links SSP2
- Partial and dynamic equilibrium (perfect market)
- Optimal technology selection
- Minimizes the total system cost
- Environmental constraints
  - Integrated Climate Model
- 15 Region Global Model
- Price-elastic demands

- Macro Stand Alone
  - Single consumer-producer, multi-regional, inter-temporal general equilibrium model which maximises regional utility.
  - The utility is a logarithmic function of the consumption of a single generic consumer.
  - Production inputs are labour, capital and energy.
  - Energy demand and energy costs from ETSAP-TIAM model.
  - MSA Re-estimates Energy Service Demands based on energy cost
Scenarios & Effort Sharing Rules

- Scenario
  - BASE SSP2
    - Our reference case scenario with all technology options available, with sectoral growth trajectories base on OECD-SSP2 value added.
  - 2DS 66% SSP2
    - The least cost solution is fixed to the base case until 2020, whereupon a cumulative carbon budget between 2020-2100 of 1000GtCO2 is enforced while CH4 and N2O are controlled by the climate module for a 2°C 2100 temperature.

- Effort Sharing Rules
  - “Contract and Converge” Per Capita Emissions
    - Equalise Regional GDP loss
    - Compensate developing countries for energy cost increases
    - Compensate developing countries for GDP loss
  - Brazil rule 1– cumulative equity “past and future”
  - Brazil rule 2 – cumulative “future equity” of remaining CO2 budget.
CO₂ Budgets + SSP2 drivers

Data: CDIAC/GCP/IPCC/Fuss et al 2014

Scenario categories:
- >1000 ppm CO₂eq
- 720–1000 ppm
- 580–720 ppm
- 480–580 ppm
- 430–480 ppm

2016 Estimate

Historical emissions

net-negative global emissions

RCP8.5
3.2–5.4°C relative to 1850–1900

RCP6
2.0–3.7°C

RCP4.5
1.7–3.2°C

RCP2.6
0.9–2.3°C

Global Carbon Project
CO₂ Abatement Cost

Marginal Abatement Price

- **2DS 66% SSP2 - Partial Equilibrium**
- **2DS 66% SSP2 MSA - General Equilibrium**
Method: Effort Sharing Process

**Global Carbon Project**
- Historical Emissions Database
  - tCO₂ 1750 - 2100 Cumulative Emissions

**TIAM - MACRO**
- Times Integrated Assessment Model
  - $/tCO₂ Carbon Price
  - $ GDP Change

**United Nations Populations Projections 1950 - 2100**
  - #People Population

**Equity Rules**
- Contract & Converge Compensation
- Brazilian Proposal

**GDP Impact of Effort Sharing**
- Carbon Budget Debt
- Interregional Capital Transfer
- tCO₂ Carbon Market Volume
Carbon Budgets; Past and 2°C

Cumulative Emissions (GtCO2)

Increasing GDP/Capita

AFR  IND  ODA  CHI  FSU  CSA  MEA  MEX  EEU  SKO  AUS  WEU  CAN  JPN  USA

Equal Per Capita Budget (1750 - 2100)  Historical Emissions (1750-2010)  Future 2C Budget

1,000 GtCO₂

*2,200 GtCO₂

*3,200 GtCO₂
Effort Sharing Rules – (1) Contract & Converge

tCO2 / Capita yr

AFR
AUS
CAN
CHI
CSA
EEU
FSU
IND
JPN
MEA
MEX
ODA
SKO
USA
WEU
GBL

AFRICA
CANADA
CHINA
AFRICA

2020 2030 2040 2050 2060 2070 2080 2090 2100
Effort Sharing Rules – (3) Future Equity
Effort Sharing Rules – (3) Future Equity

Share of Annual Emissions tCO2/yr

USA
JPN
CAN
WEU
AUS
SKO
EEU
MEX
MEA
CSA
FSU
CHI
ODA
IND
AFR

2020 2030 2040 2050 2060 2070 2080 2090 2100
GDP Impacts by 2100

% GDP Change

2DS  Contract & Converge  Past and Future Equity  Future Equity
Equitable Capital Transfers
(undiscounted)

Equalise GDP Loss

Compensate DC E-cost

Compensate DC GDP

[Graphics showing capital transfers by country and year, with colors and values indicated]
West Europe

- Europe’s cumulative GDP loss in the least cost 2DS solution is 3.3%. Europe has already emitted its equitable share of emissions and so trades accordingly causing GDP losses of 3% - 10% GDP depending upon the share of future emissions allowed to be emitted.

- Capital Transfer range: -$1.2 Tn to -$14.2Tn (discounted at 5%)
  - -$7.6 Tn to -$134 Tn (undiscounted 2020 - 2100)
Japan

- Japan’s cumulative GDP loss in the least cost 2DS solution is 2.9%. Japan has already emitted its equitable share of emissions and so trades accordingly causing GDP losses of 3% - 8% GDP depending upon the share of future emissions allowed to be emitted.

- Capital Transfer range: -$600 Bn to -$3.5Tn (discounted at 5%)
  - -$3.5 Tn to -$33 Tn (undiscounted 2020 - 2100)

% GDP Change

-3%   -6%   -8%   -3%
China

• China’s cumulative GDP loss in the least cost 2DS solution is 6.1%. The “Future Equity” effort sharing rule (3) causes relative GDP losses of 7% but less than the other effort sharing rules presented.

• Capital Transfer range: -$4.9 Tn to -$8.5Tn (discounted at 5%)
  • -$43 Tn to -$114 Tn (undiscounted 2020 - 2100)
India

- India’s cumulative GDP loss in the least cost 2DS solution is 4.8%. Again the “Past & Future Equity” effort sharing rule (2) causes relative GDP growth of 2.5%.
- Capital Transfer range: +$1.7 Tn to +$16.5Tn (discounted at 5%)
  - -$38.9 Tn to +$168 Tn (undiscounted 2020 - 2100)
Africa’s cumulative GDP loss in the least cost 2DS solution is 5.4%. The “Past & Future Equity” effort sharing rule (2) causes relative GDP growth of 34% given the continents lack of responsibility and population growth.

- Capital Transfer range: +$5.6 Tn to +$30.6Tn (discounted at 5%)
  - -$36 Tn to +$311 Tn (undiscounted 2020 - 2100)

![Graph showing GDP change for Africa]
Conclusions

- Equitable effort sharing is critical for success of the Paris Agreement.
- GDP losses in the utility maximising least cost scenario for delayed action to 2020 is regionally varied and inequitable.
- Equitable Capital Transfers should not become wealth redistribution.
- Equitable capital transfers do not negate the requirement to also decarbonise developed regions internal energy systems.

- Some future effort sharing scenarios are more equitable than others.
  - 2DS - -2.9% GDP to -11.6% GDP
  - 1 – Contract & Convergence 82% GDP to -17.3% GDP
  - 2 – Past and Future Equity - +32.6% GDP to -25.5% GDP
  - 3 – Future Equity - +42% GDP to -85% GDP

- Annual equitable capital transfers can be delayed by the burden sharing rules.
- Some rules are considerably higher than the €100bn from the Paris Agreement.
  - 1 – Contract & Convergence - $300Bn/yr by 2030
  - 2 – Past and Future Equity - >$1Tn/yr by 2020
  - 3 – Future Equity - >$450Bn/yr by 2030

- Equitable burden sharing rules require high capital transfers of trillions US $ between 2020 - 2100 (*Discounted at 5%/yr)
  - 1 – Contract & Convergence - $Tn 15 ($Tn 342 - undiscounted)
  - 2 – Past and Future Equity - $Tn 65 ($Tn 660 - undiscounted)
  - 3 – Future Equity - $Tn 17 ($Tn 78.4 - undiscounted)
Environmental Research Institute
Instiúd Taighde Comshaoil

Energy Policy and Modelling Group
www.ucc.ie/energypolicy
TIMES Energy System Model

**Cost and emissions balance**

- Prices
- Capacities
- Energy flows
- Emissions
- Costs

**Energy prices, Resource availability**

- Domestic sources
- Imports

**Primary energy**

- Coal processing
- Refineries
- Power plants and Transportation
- CHP plants and district heat networks
- Gas network

**Final energy**

- Industry
- Commercial and Tertiary
- Households
- Transport

**Service Demands**

- GDP
- Process
- Heating area
- Population
- Light
- Comms
- Power
- Person kilometers
- Freight kilometers

**Service Demands**

- Domestic sources
- Imports
ETSAP-TIAM
Reference Energy System

Fossil Fuel Reserves (oil, coal, gas)

Extraction

Upstream Fuels

Transformation (refinery, gas liquef. etc.)

Carbon capture

Carbon sequestration

Terrestrial sequestration

Biomass Potential

BIO**

Renewable Potential

Electricity Fuels

Power plants

Cogeneration

Heat

Industri

Industrial Tech.

Auto Production

Cogeneration

Agriculture Tech.

Commercial Tech.

Residential Tech.

Transport Tech.

End Use Fuels

IND***

INDEL C

INDEL C IS**

AGR***

COM***

RES***

TRA***

N2O options

CH4 options

Landfills

Manure

Bio burning, rice, enteric ferm

Wastewater

Primary energy prices, Resource availability

GDP, Population, Industrial Activity

Min \( NPV = \sum_{r=1}^{R} \sum_{y=YEARS} (1 + d_{r,y})^{REFYR-y} \cdot ANNCOST(r, y) \)

Primary energy
- Domestic sources
- Imports
- Crude Oil
- Raw Gas
- Coal
- Transformation
- Refinery, Power Plants, Gas Network, Briquetting...

Final energy
- Consumption
- Industry, Services, Transport, Residential...
- Gasoline
- Natural Gas
- Electricity

Service Demands
- Res Heat
- Ind Heat
- Person Km
- Freight Km...

MACRO Stand Alone (MSA)
General Equilibrium
Macroeconomic Model

Energy Costs
- Labour
- Capital
- Investment
- Consumption

Max \( U = \sum_{t=1}^{T} \sum_{r} nwt_t \cdot pwt_t \cdot dfact_{r,t} \cdot ln(C_{r,t}) \)

Demand Response

Capacities
Prices
Energy Flows
Emissions
Costs
GDP
ETSAP–TIAM MSA (TMSA)  
Macro Stand Alone

\[ \text{Min } NPV = \sum_{r=1}^{R} \sum_{y \in \text{YEARS}} (1 + d_{r,y})^{\text{REFY}_{r-y}} \cdot \text{ANNNCOST}(r, y) \]  
\[ \text{Max } U = \sum_{t=1}^{T} \sum_{r} nwt_r \cdot pwt_t \cdot dfact_{r,t} \cdot \ln(C_{r,t}) \]  
\[ Y_{r,t} = C_{r,t} + \text{INV}_{r,t} + \text{EC}_{r,t} + \text{NTX}(nmr)_{r,t} \]  
\[ Y_{r,t} = \left( akl_r \cdot K_{r,t}^{\text{kpvs}_{r} \cdot \rho_{r}} \cdot l_{r,t}^{(1-\text{kpvs}_{r})\rho_{r}} + \sum_{k} b_{r,k} \cdot \text{DEM}_{r,t,k}^{\rho_{r}} \right)^{\frac{1}{\rho_{r}}} \]  

- \text{nwt} – Negishi Weights
- \text{pwt} – weight Multiplier
- \text{dfact} – utility discount factor
- \text{C} – Consumption
- \text{Y} – Production
- \text{INV} – Investment
- \text{EC} – Energy Cost
- \text{NTX} – Net exports
- \text{akl} – production fn constant
- \text{K} – Capital
- \text{kpvs} – capital value share
- \text{l} – Labour annual growth
- \text{b} – Demand coefficient
- \text{p} – elasticity of substitution
- \text{DEM} – Energy Demands
National Determined Contributions and resultant GHG Global Pathways

- Pre-INDC scenarios (High Cancun pledge scenarios) until 2030 with const. policy thereafter (n = 31; Ampere HST PS in IPCC AR5 scenario database)
- Min/max of conditional & unconditional INDC ranges, globally aggregated
- Reductions below reference scenarios due to INDCs (median)
2C Pathways, and delayed action to 2030
1.5C scenarios with Delayed Action