How can Climate be taken into account in National Accounts ?
An Insee Proposal to « augment » National Accounts

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Strengths and limits of national accounts

GDP : A Measure of the economic activity, but …

- Boundary limited to production generating monetary flows (with some exceptions)
- Does not account for inter-temporal effects (vs. NDP-type indicators, which substract CCF)
- Valuation at market prices: externalities are not incorporated

System of National Accounts (SNA)

- Detailed description of the economy: activity by industry and asset type
- Ensures overall consistency :
  - Transactions are recorded for clearly identified institutional agents,
  - Accounting is designed so that all transactions between agents are balanced
- Based on observed monetary flows between agents, and a comprehensive system of statistical information.

Question: How can the SNA be adapted to capture the consequences of climatic damage?

- Provide information on the ‘real’ state of the economy, including sustainability aspects (cf. SNA 2025)
- Highlighting the costs of greenhouse gas (GHG) emissions
- Does address economic optimality - the SNA is descriptive, not prescriptive

Greenhouse Gas emissions and GDP

Relations between emissions and activity

- **Cost of emitting GHG :**
  - Increases in temperature, sea level, ...
  - Affects activities that depend on climate : **damage costs**
  - Long term effects that may last for centuries
- **Cost of not emitting GHG :**
  - Many economic activities cause GHG emissions
  - Mitigation policies would restrict such activities : **mitigation costs**
  - Shorter-term effects
- Effects beyond **GDP** :
  - Effects on health or mortality of climate damages
  - Such considerations will induce mitigation policies
  - Assessing the sustainability and the performance of an emitting economy

Adapting the accounts framework

New sectors :

- ***Climate* Sector :**
  - Produces a **climate service** used as an intermediate input by other sectors and households
  - This service deteriorates as the atmospheric stock of CO_2 increases, i.e. degradation of the **climate asset**
  - The loss in value of this service can be assessed by estimating the future damages caused by current emissions (*social cost of carbon*)
- ***Carbon regulator* Sector :**
  - Produces **GHG emissions rights** used as intermediate inputs by emitting sectors
  - Mitigation policies cap total allowable carbon emissions : the **carbon budget**
  - Emission valuation is based on the **shadow price of carbon**, reflecting the cost of abatement

Lessons learned from this adaptation

- The **SNA balance sheet** already incorporates some future damages through the *market valuation of assets*
  - The proposed adaptation makes **these damage costs** more explicit
  - **Value is transferred** between existing and new agents:
    - externalities may affect prices, but **not total value added or aggregated wealth**
  - **Costs are recorded as asset consumption** (climate and carbon budget):
    - This adjusts *net indicators* such as **Net Domestic Product** (NDP) or **Net Saving** (NS)
- Both **damage** and **mitigation costs** should be accounted for
  - GHG emissions increase future damages → *climate asset*
  - Mitigation policies limit GHG emissions → *carbon budget*
  - Different accounting adjustments for sectors that **emit** or **suffer** from GHG emissions (some sectors may be both)
- **Accounting for damages to household (« beyond »)** alters standard indicators
  - Extends beyond the production boundary of SNA
  - Defines **extended consumption**: closer to a measure of *well-being*

Valuation of damage costs

- The climate sector provides $A_{s,\tau}$ services to industry *s* at time $\tau \geq t$ that depends on the atmospheric carbon stock $S_t^{CO_2}$:

$A_{s,\tau}(S_t^{CO_2}) \approx \bar{A}_s - c_{s,\tau}\left(E(S_\tau^{CO_2}|I_t) - S_{t_0}^{CO_2}\right)$, $c_{s,t}$ being the marginal damage induced by a supplementary ton of CO_2 in the atmosphere, and I_t the information available at date *t.*

- Hence, the actualized loss of value induced by total emissions at date *t* $E_t = \sum E_{s,t}$:

$$-E_t \sum_{\tau=t+1}^{\infty} \frac{\sum_s c_{s,\tau}(S_t^{CO_2}, I_t)}{(1+r)^{\tau-t}} = -C_t(S_t^{CO_2}, I_t)$$

Since the increase of the stock is permanent.

- $C_t(S_t^{CO_2}, I_t)$ is the social cost of carbon, as defined in Rennert et al. (2022)
- *r* is the discount rate
- Potential **breakdown of the damages** affecting the industry, distinguishing activities **within and beyond** the GDP production boundary, variability of $c_{s,\tau}$
- Potential **breakdown of the damages induced by** industry emissions, variability of $E_{s,t}$
- This requires **projecting damage costs**, which may themselves depend on **future emissions** because of the **convexity of the damage function**.

Valuation of mitigation costs (1)

- **Mitigation policies** are implemented through regulation and/or taxation with the objective of complying with a **carbon budget** $BC_t = \sum_{\tau \geq t} E_\tau$.

- From the **perspective of a social planner**: the carbon budget constitutes a **constraint** that must be incorporated into an **intertemporal optimisation program**.
  - **Optimal choice of decarbonisation** technologies (based on their abatement cost)
  - Such a program yields the corresponding **sequence of future emissions**
  - Let γ_t denote **the shadow price** associated to the **carbon budget constraint** at date t, γ_t follows **Hotelling's rule**, $\gamma_{t+1} = \gamma_t(1 + r)$ reflecting the **depletion** of a non-renewable asset.
- Here, E_t corresponds to the **consumption of carbon budget**, and should be priced γ_t
- The sequence $(\gamma_t, \gamma_{t+1,\dots})$ represents the carbon prices that should be implemented in order to induce, in a decentralised equilibrium, the emission path $(E_t, E_{t+1,\dots})$ consistent with the carbon budget constraint.

Valuation of mitigation costs (2)

- **Interpretation:**
  - γ_t is the **implicite price paid** to **the carbon regulator** for emitting at date *t*. Its discounted value is given by: $\sum_{\tau \geq t} \frac{\gamma_\tau E_\tau}{(1+r)^{t-\tau}} = \sum_{\tau \geq t} \gamma_t E_\tau = \gamma_t BC_t$.
  - The **value of the carbon budget** can therefore be interpreted as the discounted cost of mitigation policies and, as such, a measure of the effort required to decarbonise the economy.
  - These costs are implicitely included within the GDP production boundary, although they are not separately identified.
  - In the absence of mitigation policies, this value would be zero.

- **Implementation in the French case**
  - The **Quinet Commission** (2019 and 2025) provides estimates of this shadow price and its trajectory under the name **Climate Action Value** (« Valeur d'action pour le climat »)
  - These estimates are derived from on techno-economic macroeconomic models, optimised under the Carbon Budget constraint.
  - They implicitely Assume some degree of rationality and intertemporal consistency in the implementation of mitigation policies.

Data on carbon prices

Prices (External information)

- **Social cost of carbon** – *Rennert et al., Nature* (2022)
  - Provides information on the basic components of the damage function
  - Decomposes impacts **within GDP** and **beyond GDP** (e.g., health and mortality effects)
  - Subject to **high uncertainty**
- **Shadow price of carbon** – *Quinet* (2019), "*Climate Action Value*"
  - Derived from techno-economic and macroeconomic models (*abatement cost approach*)
  - **Highly sensitive** to mitigation policies and their implementation

Figure 2 - Social cost of carbon and value of climate action (VCA - shadow price of carbon)

in current euros/ton CO_2 eq

Carbon price	2018	2019	2020	2021	2022	2023
Social cost of carbon	**146**	**149**	**154**	**157**	**162**	**172**
Within the GDP boundary	77	78	81	82	85	90
Beyond the GDP boundary	70	71	73	75	77	82
Value of Climate Action (VCA)	**109**	**115**	**124**	**131**	**141**	**154**

Which synthetic indicators ?

- **GHG Emissions as Capital Consumption**
  - **Climate asset**: As GHG emissions degrade climate assets, they are treated as a form of *capital consumption*.
    - **Effect of French emissions on global wealth**:
      - Production-based approach — *CNC-World* ("Attribution").
    - **Effect of global emissions on French wealth**:
      - Income-based approach — *CNC-Fr* ("Adjustment").
    - **Carbon budget**: Emissions tighten mitigation constraints — *CCB*.
  - In both approaches, emissions reduce wealth, thereby lowering adjusted economic indicators.
- **Adjusted Indicators of Economic Activity**
  - Reflect the **sustainability** of economic activity in a given year.
  - **Net Domestic Product (*NDP*)** = *GDP* – Consumption of Fixed Capital (*CFC*)
  - **Adjusted NDP (*NDPA*)** = *NDP* – *CNC-World* – *CCB*
  - **Net Saving (NS)** = Gross Disposable Income (*GDI*) – Final Consumption – *CFC*
  - **Adjusted Net Saving (*NSA*)** = *NS* – *CNC-Fr* – *CCB*

Contributions and adjusted indicators

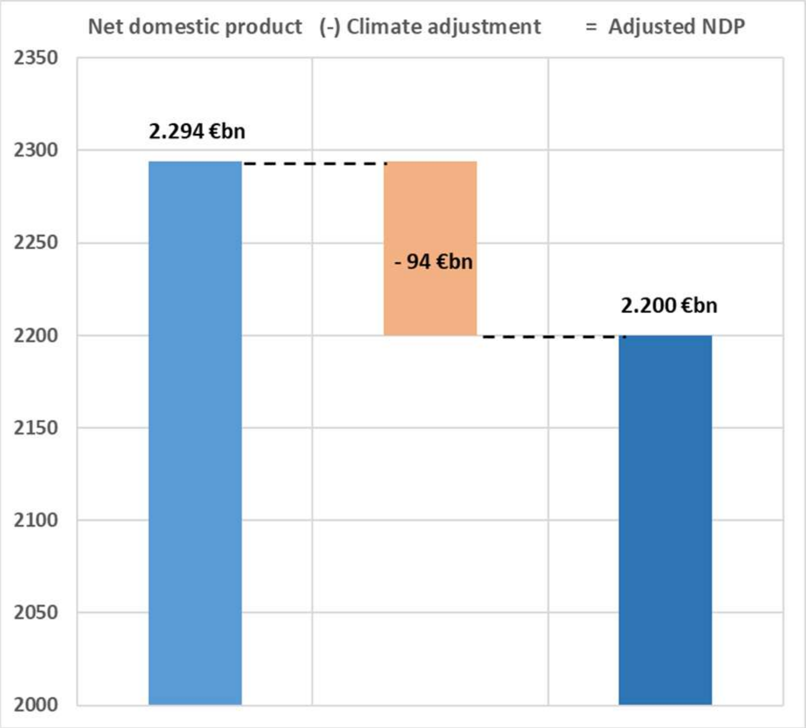
Figure 3 - Contribution of emissions to the adjustment of NDP and net savings

in billions of current euros

Contributions and aggregated and extended indicators	2018	2019	2020	2021	2022	2023
Global damage linked to French emissions	**70**	**69**	**64**	**69**	**69**	**69**
Within the GDP boundary (A)	37	36	34	36	36	36
Beyond the GDP boundary (AH)	33	33	30	33	33	33
Global damage linked to France's carbon footprint	**104**	**103**	**96**	**104**	**109**	**111**
Within the GDP boundary	54	54	50	55	57	58
Beyond the GDP boundary	49	49	45	50	52	53
Damage in France linked to global emissions	**225**	**230**	**229**	**243**	**254**	**274**
Within the GDP boundary (B)	118	120	120	127	133	144
Beyond the GDP boundary (BH)	107	109	109	116	121	131
Consumption of the carbon budget (C)	**48**	**49**	**48**	**54**	**56**	**57**
Aggregated and extended indicators						
Net domestic product (NDP)	1 951	2 010	1 882	2 047	2 153	2 294
Adjusted net domestic product (ANDP), (NDP-(A+C))	1 867	1 924	1 800	1 957	2 061	2 200
Extended ANDP, (ANDP-AH)	1 833	1 892	1 770	1 924	2 028	2 167
Net savings (NS)	111	148	48	129	89	68
Adjusted net savings (ANS), (NS-(B+C))	-55	-21	-120	-52	-100	-133
Extended ANS (ANS-BH)	-162	-130	-229	-168	-221	-264

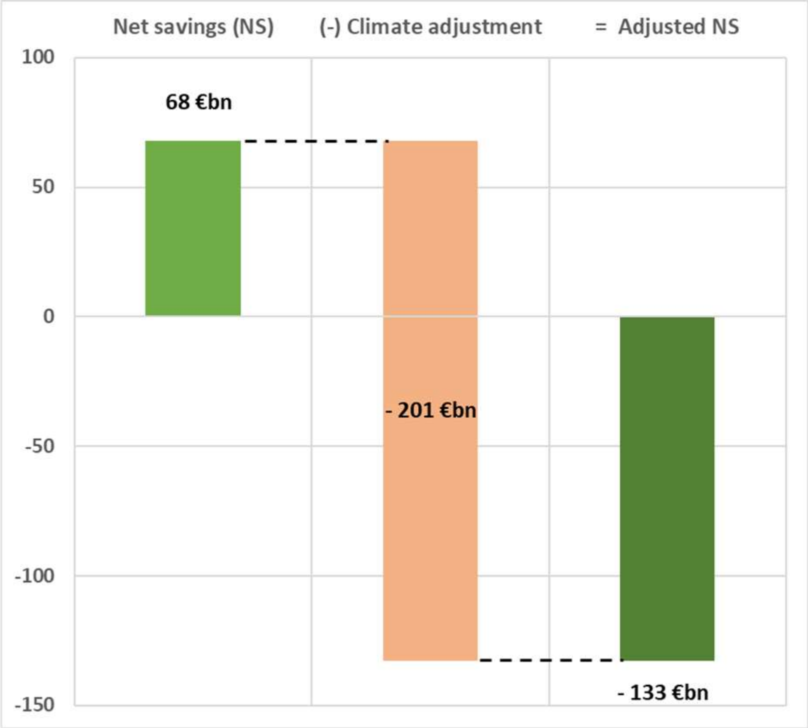
Notes: The figures shown in this table result from the authors' calculations and are based on past figures. The valuation of the damage caused in France by global emissions is based on its share of global GDP, which amounts to 3%. These are orders of magnitude that may be considerably altered with the use of more precise sources seeking to evaluate damage specific to France. The extended ANDP and ANS also serve to reduce them for damage occurring beyond the GDP boundary.

An adjustment of -94 bn€ to move from NDP to NDPA -201 bn€ to move from NS to ANS



Net domestic product reduced by 94bn€, i.e. **-4,1%**

If we extend ‘beyond the production frontier’ to take account of health/morbidity costs → -5,5%

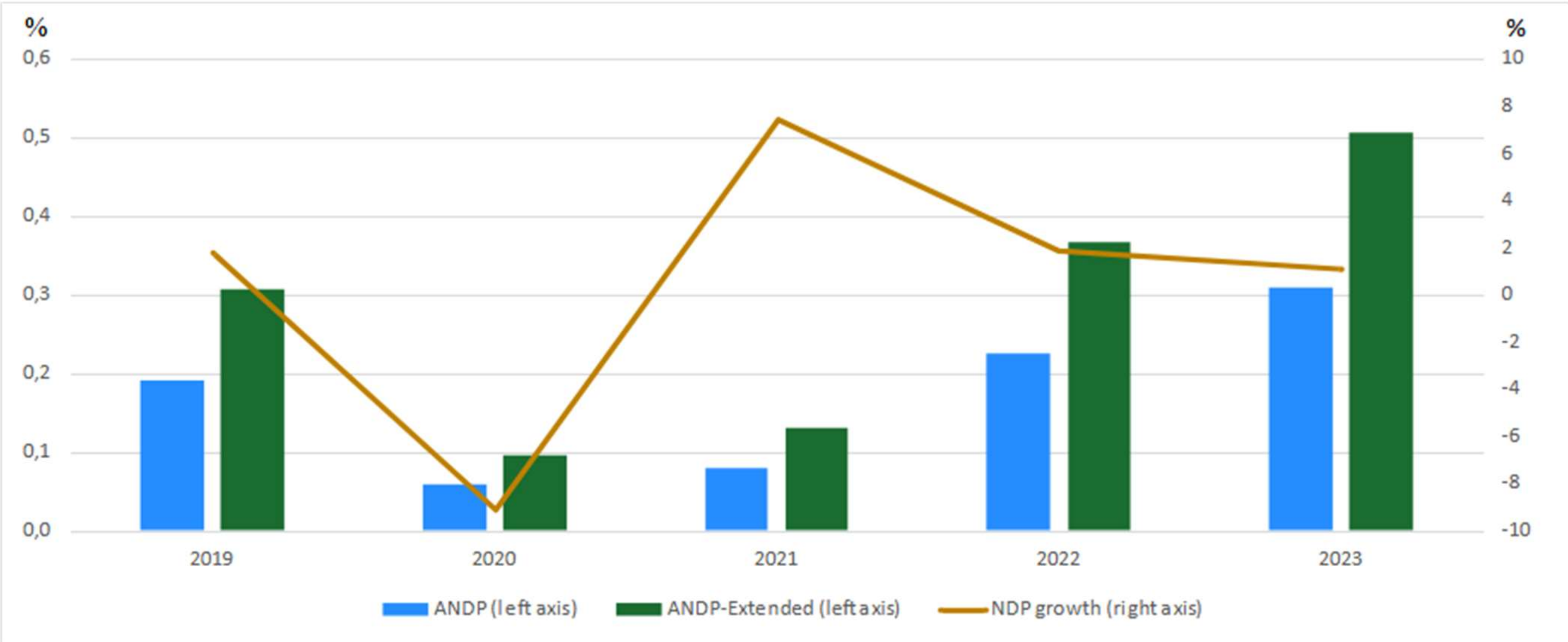


Adjusted net savings reduced by **€200bn**

Negative adjusted net savings, unlike usual savings → Indicates a lack of sustainability!

ANDP growth slightly higher than NDP growth

Volume growth differential between NDP and Adjusted/Extended NDP



Volume growths of the ANDP and extended NDP are estimated by holding the prices of their components constant at the base date and considering only changes in volumes (eg GHG emissions in teq CO2)

Other Synthetic Indicators on Carbon

- **Carbon Meter**
  - Valuation (at the social cost of carbon) of excess emissions relative to targets
  - Operational applications
- **Climate responsibility**
  - Valuation of the carbon stock for which France is “responsible,” based on the social cost of carbon
  - Cumulative French carbon footprint since 1850
- **Carbon Budget**
  - Valuation of the remaining carbon budget using the shadow price of carbon
  - Anticipated cost of decarbonising the economy

Wealth Indicators

Figure 5 - Valuation of assets linked to carbon emissions

in billions of current euros

Category	2018	2019	2020	2021	2022	2023
Deterioration of the climate linked to excess emissions - carbon meter	**-3**	**-5**	**-12**	**-14**	**-16**	**-21**
Within the GDP boundary	-1	-2	-6	-7	-9	-11
Outside of the GDP boundary	-1	-2	-6	-6	-8	-10
Retrospective climate responsibility (cumulative footprint)	**5 437**	**5 637**	**5 942**	**6 142**	**6 479**	**6 964**
Within the GDP boundary	2 848	2 953	3 113	3 217	3 394	3 648
Outside of the GDP boundary	2 589	2 684	2 830	2 925	3 085	3 316
Carbon Budget	**883**	**883**	**897**	**898**	**911**	**929**
in GDP points	**37**	**36**	**39**	**36**	**34**	**33**

Conclusion

In any case, these synthetic indicators cannot have the same status as conventional national accounting indicators — they should be considered **experimental statistics.**

- They have a **strong forward-looking dimension**, as they rely on estimated prices.
- They **highlight two distinct types of costs**: damage costs and mitigation expenditures.
- They are **dependent on announced mitigation policies**, meaning the indicators are likely to undergo significant revisions over time.
- They involve the **estimation of several asset indicators**, which can be interpreted — in different ways — as climate debts.
- They go beyond a simple juxtaposition of indicators, providing:
  - a **clearer analytical framework** for interpreting the various measures, and
  - a **consistent linkage** between national accounting indicators and emissions (both footprint and inventory), in line with the **ANA approach**.

Finally, this framework underscores the importance of **regular updates** to reflect evolving parameters:

- the **damage trajectory** affecting France, by sector and by household,
- the **anticipated emissions trajectory**, consistent with mitigation policies, and
- the **shadow price of carbon** (climate action value) and the **social cost of carbon**.

Adaptation to the valuation of Ecosystems ?

Principles :

- Considering the loss of value induced by ecosystem degradations :
  - Standard approach for ecosystem valuation.
  - Emphasises the economic consequence of ecosystem degradatation, although the analysis could be extended beyond purely economic dimensions.
- Accounting for policies aimed at preserving ecosystems.
  - Cost-based approach
  - Emphasizes the efforts undertaken to limit ecosystem degradation
- Patrimonial perspective, insofar as such degradation may occur over long time horizons

Implementation :

- Need to identify an objective “measure” of ecosystem quality.
  - Carbon stock in the climate case
- The cost-based approach would require to define ecological constraints, to which shadow prices could be associated:
  - However, which measurable variable should be considered as the ecosystem equivalent of carbon emissions ?

Merci

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Data on GHG Emissions

GHG Emissions inventory and footprint (Insee and SDES)

- **Production-based approach :**
  - **Air emission accounts** with monetary production and value added
- **Demand-based approach :**
  - **Carbon footprint** with monetary final demand (use of the MRIO model FIGARO)

Figure 1 - Greenhouse gases (GHG) emissions in France and globally

GHG emissions	2018	2019	2020	2021	2022	2023
Emissions by resident economic units (France, Mt CO_2 eq)	475	464	416	440	427	403
Territorial emissions - inventory in SNBC format (Mt CO_2 eq)	439	429	389	412	396	373
Carbon Budget based on SNBC 2 (Gt CO_2 eq)	8,1	7,7	7,2	6,9	6,4	6,0
Carbon Meter (Mt CO_2 eq)	-18	-31	-77	-87	-100	-123
Footprint (France, Mt CO_2 eq)	704	691	620	666	671	644
Cumulative footprint since 1850 (Gt CO_2)	37,2	37,9	38,6	39,2	39,9	40,5
Global emissions (Gt CO_2 eq)	**51,0**	**51,3**	**49,3**	**51,6**	**52,0**	**53,0**