Environmental and Natural Resource Economics

Ecosystems Economic Valuation

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MSc in
Law and Economics
in Energy Markets

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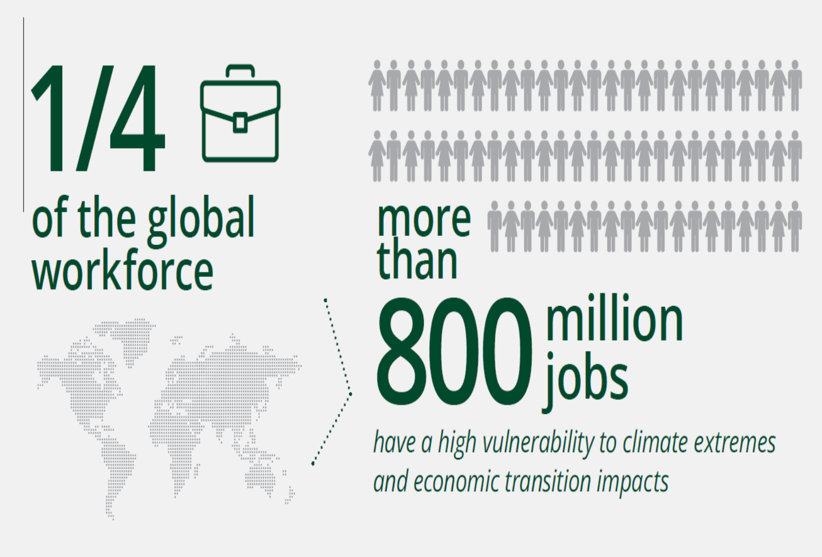
  Market-based measures **undervalue** Environmental Benefits
- Valuation necessary for Environmental Managers $\rightarrow$ Economic and Environmental Policies

Deloitte Net Zero Report (Link)



Definitions

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Ecosystem Functions

Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem; in other words, what the ecosystem does. Some examples of ecosystem functions are provision of wildlife habitat, carbon cycling, or the trapping of nutrients

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2. Identification of ***Public's Values***
3. ***Comparing*** Benefits of different projects/programs
4. ***Prioritization*** Conservation or Restoration projects
5. Maximize ***Efficiency*** of environmental benefits (per €spent)

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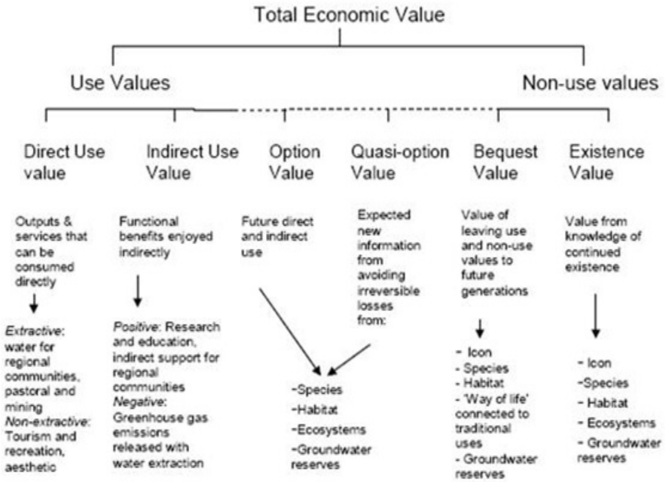
- Standard disaggregation
  - **Use Value**
  - **Non-Use Value**
  - **Option Value**

Valuation Classification



Source: Rolfe (2010)

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- **Indirect Use Value (IUV)**
  - ***Functional Values*** associated ES with support for Human needs rather than directly using Resources
  - E.g. Regulation of chemical composition of the atmosphere and ocean/ climate & water regulation/ soil retention and provision

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  - having the option to use a resource ***in the future***
  - Expressed as the Amount people are willing to pay to conserve certain Ecosystem attributes (e.g. a national park)

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- **Quasi-Option Value (QOV)**
  - $\uparrow$ Scientific Knowledge of potential harnessing of Environmental Resources which could be of use in the future
  - Value of information that can be secured by delaying a decision with uncertain outcomes
  - E.g. Development of a piece of forested land for agricultural use $\rightarrow$ known benefits in terms of crops but ***unknown*** benefits of preserving the same piece of land . Delaying the decision $\rightarrow$ learn more about the benefits of preserving

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- **Existence Value**
  - Existence of an ecosystem resource, even though an individual has no actual or planned use of it

    E.g. Valuing existence of blue whales despite probably never seeing one

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- Connecting Economic and Intrinsic value implies broader incentives
  - **Bequest**: Associated with future generations use
  - **Donating**: In the form of gifts $\rightarrow$ Use Value
  - **Empathy**: Towards Nature and other Human Beings
  - **Recognition of non-Human Rights**

Critique on Valuation

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- **Existence Value** is inherent in all living creatures → should not be included in Cost-Benefit Analysis (Rosenthal & Nelson, 1992)
- **Option Value** is tied to Potential Use → included in **Use Value** (Kolstad, 2000)

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  Data individuals' preferences for a marketable good which includes environmental attributes

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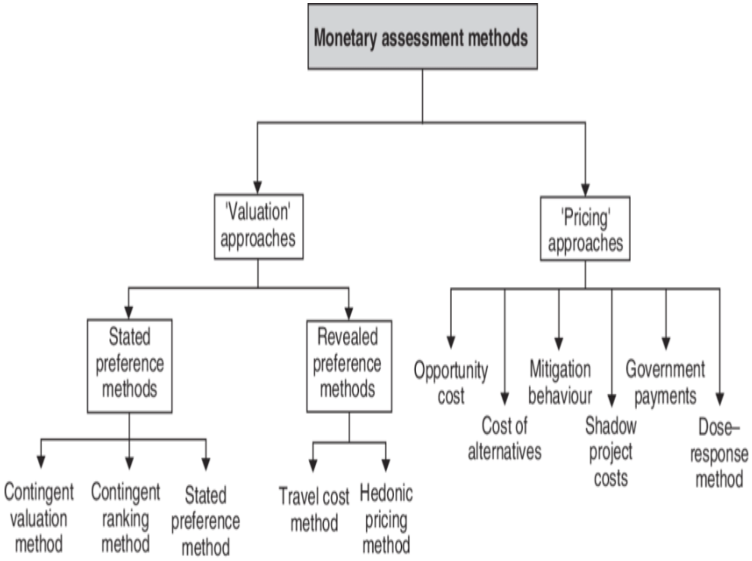
- **Revealed Preferences Methods**
  Data individuals' preferences for a marketable good which includes environmental attributes
- **Stated Preferences Methods**
  Questionnaires to evoke individuals' preferences for a given change in a natural resource or environmental attribute

Ecosystem Valuation Methods



Appropriate Valuation Methods

Valuation method	Element of TEV captured	Ecosystem service(s) valued	Benefits of approach	Limitations of approach
Market prices	Direct and indirect use	Those that contribute to marketed products e.g. timber, fish, genetic information	Market data readily available and robust	Limited to those ecosystem services for which a market exists.
Cost-based approaches	Direct and indirect use	Depends on the existence of relevant markets for the ecosystem service in question. Examples include man-made defences being used as proxy for wetlands storm protection; expenditure on water filtration as proxy for value of water pollution damages.	Market data readily available and robust	Can potentially overestimate actual value
Production function approach	Indirect use	Environmental services that serve as input to market products e.g. effects of air or water quality on agricultural production and forestry output	Market data readily available and robust	Data-intensive and data on changes in services and the impact on production often missing
Hedonic pricing	Direct and indirect use	Ecosystem services that contribute to air quality, visual amenity, landscape, quiet i.e. attributes that can be appreciated by potential buyers	Based on market data, so relatively robust figures	Very data-intensive and limited mainly to services related to property
Travel cost	Direct and indirect use	All ecosystems services that contribute to recreational activities	Based on observed behaviour	Generally limited to recreational benefits. Difficulties arise when trips are made to multiple destinations.
Random utility	Direct and indirect use	All ecosystems services that contribute to recreational activities	Based on observed behaviour	Limited to use values
Contingent valuation	Use and non-use	All ecosystem services	Able to capture use and non-use values	Bias in responses, resource-intensive method, hypothetical nature of the market
Choice modelling	Use and non-use	All ecosystem services	Able to capture use and non-use values	Similar to contingent valuation above

Source: Based on eftec (2006) *Valuing our Natural Environment*

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    1. Travel Cost Method
    2. Hedonic Price Method
    3. Costs of Illness Method
    4. Averting Behaviour & Defensive Expenditures

Revealed Preferences Methods

Method	Revealed behaviour	Conceptual framework	Types of application
Hedonic pricing	Property purchased; choice of job	Demand for differentiated products	Property value and wage determinants
Travel cost	Participation in recreation activity at chosen site	Household production; complementary goods	Recreational demand
Averting behaviour/defensive expenditure	Time costs; purchases to avoid harm	Household production; substitute goods	Health: mortality and morbidity
Costs of illness	Expenditures to treat illness	Treatment costs	Health: morbidity

Source: Boyle (2003).

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- Price of a marketed good is related to its characteristics, or the services it provides

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$$P_i = f(A_i, L_i, E_i) \tag{1}$$

- P_i: Price (e.g. House Price)
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- L_i: Location Characteristics (e.g. Public Transport, Schools)
- E_i: Environmental Characteristics (e.g. CO2 concentration)

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- Estimate the **Demand Function - Willingness to Pay** for an Environmental Characteristic
- Extra Amount of Money the consumer is willing to Pay for the Good for a **marginal increase of an Environmental Resource or Amenity** ***ceteris paribus***

House Prices Example

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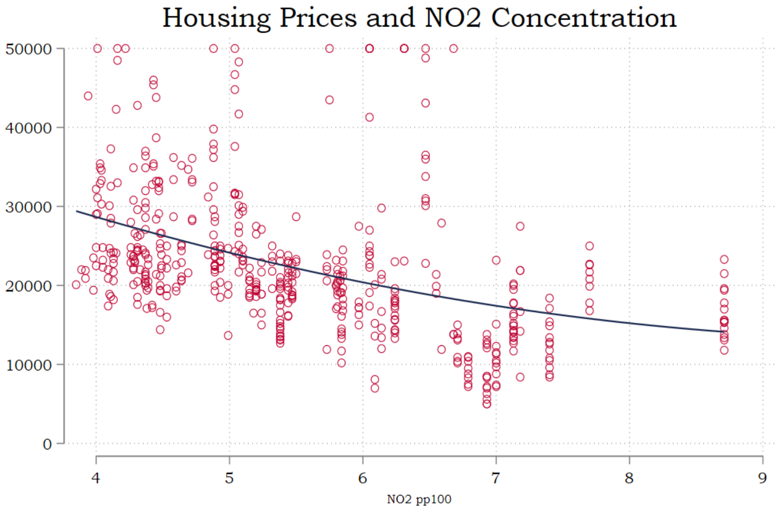
- **Estimated Partial Elasticity**: What is the $\% \uparrow \boldsymbol{P}$ for a $1\% \downarrow$ in Pollution?

House Prices and NOx Concentration



Source: Wooldridge

Regression Results

Average Housing Prices and NOx

	(1)	(2)	(3)
VARIABLES	log(Price)	log(Price)	log(Price)
log (NOx)	-1.04***	-0.45***	-0.28***
	(0.078)	(0.066)	(0.077)
Avg number of rooms		0.29***	0.28***
		(0.017)	(0.017)
Crimes committed per capita		-0.02***	-0.01***
		(0.002)	(0.002)
log(Property Tax)			-0.18***
			(0.042)
Constant	11.71***	8.96***	9.75***
	(0.132)	(0.173)	(0.253)
Observations	506	506	506
R-squared	0.264	0.598	0.612
Estimation Method	OLS	OLS	OLS

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

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- Including control variables magnitude but still Negative & Significant
- People **Value Ecosystem Quality** $\rightarrow$ reflected in House Prices

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1. **(−)**: Quality Data Requirements
2. **(−)**: Public misconception of ES
3. **(−)**: Linear Relationship Identification (***tricky***)

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- **Premise**: Travel Cost ***reflects Use Value*** of Recreational Site (e.g. lake for fishing, mountain for hiking etc.)
- Estimate **Economic Benefits or Costs** resulting from:
  - Changes in access costs for a recreational site
  - Elimination of an existing recreational site
  - + of a new recreational site
  - Changes in environmental quality at a recreational site

Travel Cost Method (cont.)

- Total Travel Cost (K) for person i visiting site j is

$$K_{ij} = f(D_{ij}, T_{ij}, E_{ij}) \tag{4}$$

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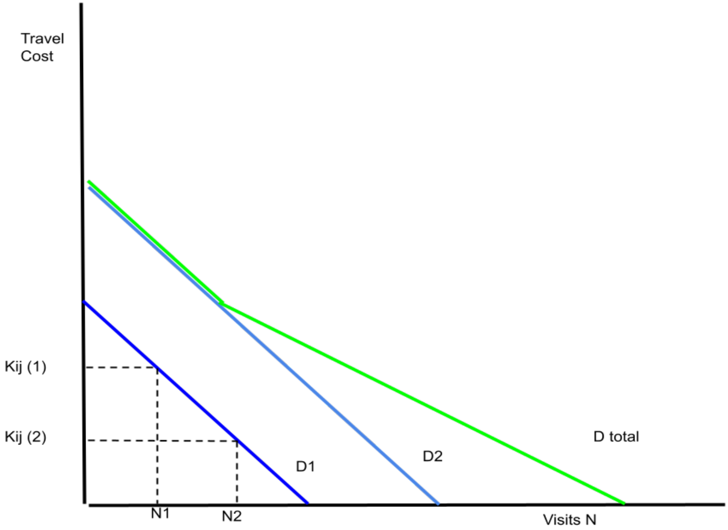
- Integrate Information with **Number of Travels (N)**
  $\rightarrow$ Estimate Demand Curve for Environmental Good (site)

Demand Curve with TCM



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   - Simple Method based on **Secondary data** for visitors' travels from **different Zones**
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   - Cannot value a **change in quality** for a site

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   - Cannot value a **change in quality** for a site
2. **Individual Travel Cost Approach**
   - Similar to the zonal approach, but **uses survey data** from visitors $\neq$ data from each zone
   - $\uparrow$ Data Requirements, $\uparrow$ Precise Results

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1. **(–)**: Assuming single purpose trip (visit the site) ***overestimates value*** if > 1 purpose
2. **(–)**: Availability of Substitute Sites distorts results
3. **(–)**: Those who value certain sites may choose to live nearby! (***Endogeneity***)
4. **(–)**: Those who live nearby certain sites tend to value them more! (***Endogeneity vol. 2***)

Temple of Poseidon TCM

- Tourkolias *et al.* (2015) apply the Zonal TCM to estimate value attributed to the **Poseidon temple in Sounio, Greece**

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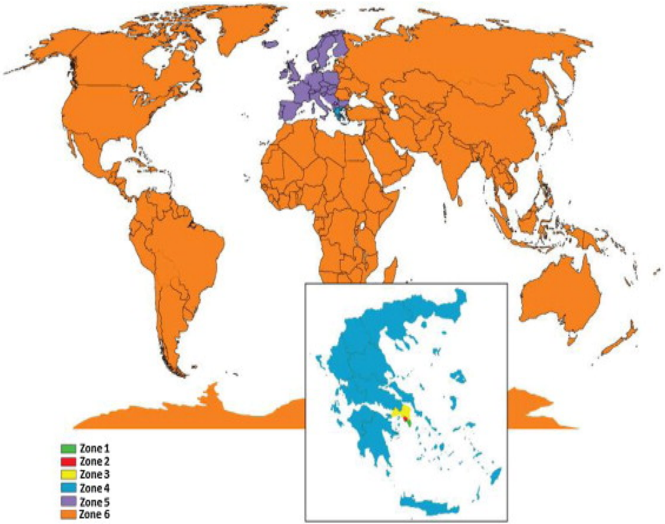
- **Total Value = CS + Total Expenditures =** 17 – 60 **€mil./year**

Travel Zones



Visitation Rates

Zones	Visitors	Population	Visitation rate (VR)
1	10,000	63,350	157,853
2	5000	316,913	15,777
3	48,000	3,381,547	14,195
4	5000	7,202,210	694
5	50,000	629,190,543	79
6	32,000	6,228,032,545	5

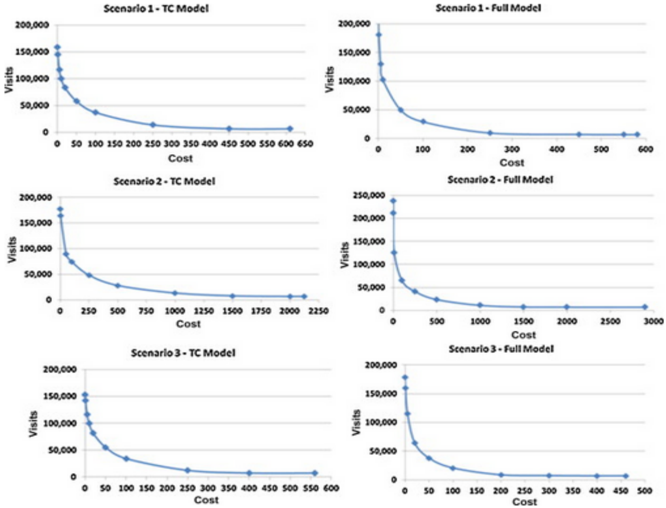
Travel Costs per Visitor

Zones	Scenario 1	Scenario 2	Scenario 3
1	4.8	4.1	8.5
2	7.1	6.4	9.6
3	12.1	9.0	18.2
4	43.1	31.9	49.8
5	141.2	418.8	154.1
6	213.6	461.7	228.6

Regression Results

Model	Scenario	Regression function	Adj. R^2	Predicted number of visitors
Semi-log 2 - TC model	1	$\ln(VR) = 10.2^{*} - 0.04(\text{travel cost})^{*}$	87.2%	168,348
	2	$\ln(VR) = 9.7^{*} - 0.02(\text{travel cost})^{**}$	75.0%	219,830
	3	$\ln(VR) = 10.4^{*} - 0.04(\text{travel cost})^{*}$	87.4%	163,600
Semi-log 2 - full model	1	$\ln(VR) = -25.5^{**} - 0.04(\text{travel cost})^{*} + 15.7(\text{freelancer})^{**} + 3.7(\text{visit})^{*\ **}$	99.2%	154,923
	2	$\ln(VR) = 14.8^{**} - 0.02(\text{travel cost})^{*} \pm 5.5(\text{gender})^{*} - 2.7(\text{education})^{**}$	99.4%	174,561
	3	$\ln(VR) = -26.4^{**} - 0.05(\text{Travel Cost})^{*} + 17.8(\text{Freelancer})^{**} + 0.6(\text{Income})^{***}$	99.3%	167,646
Double-log - TC model	1	$\ln(VR) = 15.2^{*} - 2.4\ln(\text{travel cost})^{*}$	95.4%	158,849
	2	$\ln(VR) = 13.5^{*} - 1.8\ln(\text{travel cost})^{*}$	90.9%	177,592
	3	$\ln(VR) = 16.9^{*} - 2.7\ln(\text{travel cost})^{*}$	93.8%	153,265
Double-log - full model	1	$\ln(VR) = -15.7^{**} - 2.6\ln(\text{travel cost})^{*} + 8.6\ln(\text{age})^{*}$	99.1%	205,503
	2	$\ln(VR) = 24.0^{**} - 1.8\ln(\text{travel cost})^{*} - 15.6\ln(\text{visitation reason})^{***}$	98.0%	238,495
	3	$\ln(VR) = -21.2^{**} - 3.1\ln(\text{travel cost})^{*} + 3.0\ln(\text{attractiveness})^{***} + 9.7\ln(\text{age})^{*}$	99.9%	178,722

Demand Curves



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- Based on **Random Utility Theory**
  Utility from alternative choices: ***observed + random component***

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- No actual market to estimate Use and Non-Use Value
- Mitchel & Carson (1989): ***The principal challenge facing the designer of a CV study is to make the scenario sufficiently understandable, plausible and meaningful to respondents so that they can and will give valid and reliable values despite their lack of experience with one or more of the scenario dimensions***

Elicitation Formats

Format	Description
Open ended	*What is the maximum amount that you would be prepared to pay every year, through a tax surcharge, to improve the landscape around Stonehenge in the ways I have just described?*
Bidding game	*Would you pay GBP 5 every year, through a tax surcharge, to improve the landscape around Stonehenge in the ways I have just described?* If Yes: Interviewer keeps increasing the bid until the respondent answers No. Then maximum WTP is elicited. If No: Interviewer keeps decreasing the bid until respondent answers Yes. Then maximum WTP is elicited.
Payment card	*Which of the amounts listed below best describes your maximum willingness to pay every year, through a tax surcharge, to improve the landscape around Stonehenge in the ways I have just described?* 0 GBP 0.5 GBP 1 GBP 2 GBP 3 GBP 4 GBP 5 GBP 7.5 GBP 10 GBP 14.5 GBP 15 GBP 20 GBP 30 GBP 40 GBP 50 GBP 75 GBP 100 GBP 150 GBP 200 > GBP 200
Single-bounded dichotomous choice	*Would you pay GBP 5 every year, through a tax surcharge, to improve the landscape around Stonehenge in the ways I have just described?* (the price is varied randomly across the sample)
Double-bounded dichotomous choice	*Would you pay GBP 5 every year, through a tax surcharge, to improve the landscape around Stonehenge in the ways I have just described?* (the price is varied randomly across the sample) If Yes: *And would you pay GBP 10?* If No: *And would you pay GBP 1?*

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1. **(+)**: Based on what people say they would do $\neq$ people are observed to do
2. **(+)**: Very **flexible** $\rightarrow$ can be used to estimate the economic value of virtually anything

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1. **(–)**:Based on what people say they would do ≠ people are observed to do
2. **(–)**: Assumes people ***understand the good in question*** and will reveal their preferences as they would in a real market
3. **(–)**: Respondents may express a positive WTP to feel good about giving for a social good (***warm glow effect***)
4. **(–)**: Respondents may express zero WTP the good because they are protesting some aspect of the scenario (e.g. paying taxes)

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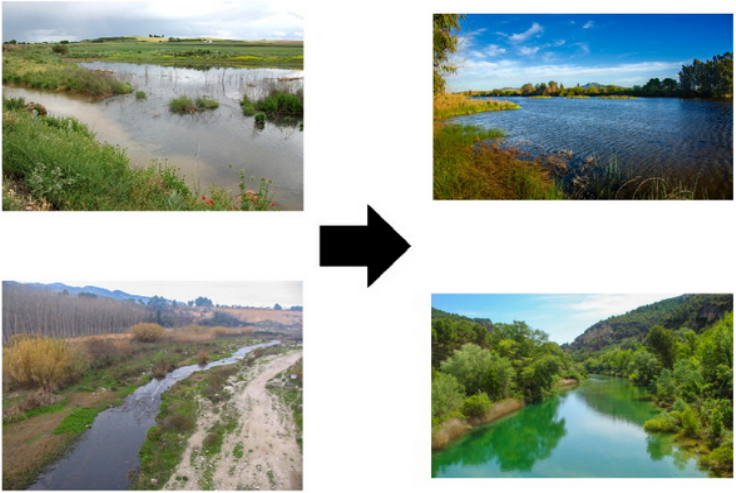
- Multiplied by number of families in the region
  → **39 million €per year**

Ecological Status Guidana River Basin



Bad ecological status **Good ecological status**

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- Brazil's Minister of the Environment "The opportunity cost must be paid by someone, and ... someone means those who have the funds or the necessary sources of finance for that." Estimated the cost: $12 billion a year

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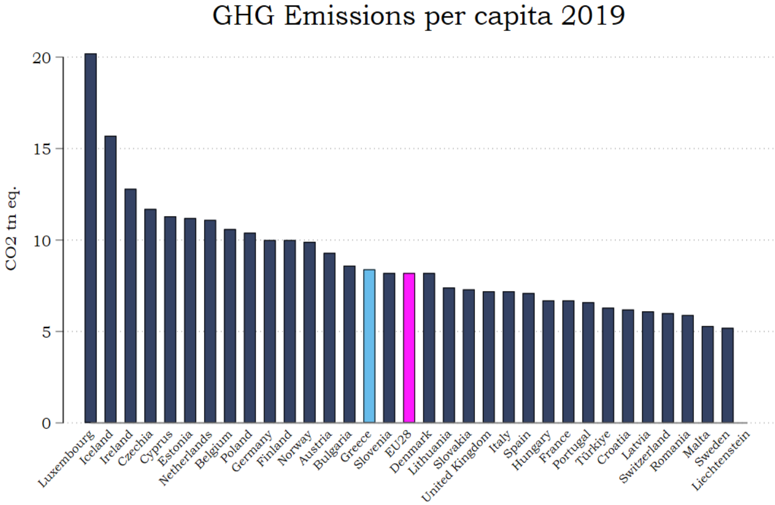
- Average Greek emits 5.6 tonnes of CO2 in 2019 $\rightarrow$ **280 $ per year**

GHG Emissions per Inhabitant



Source: Eurostat

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- Over twenty climate change IAMs summarized here

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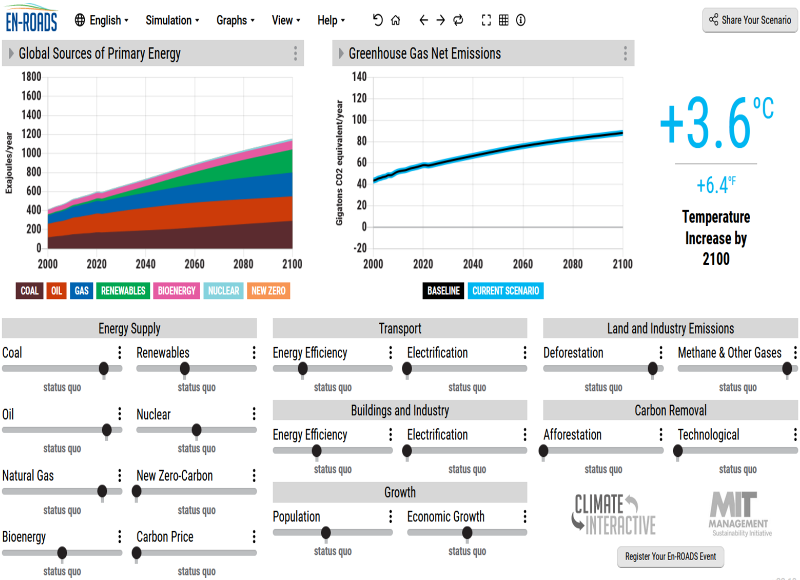
ENROADS Interface



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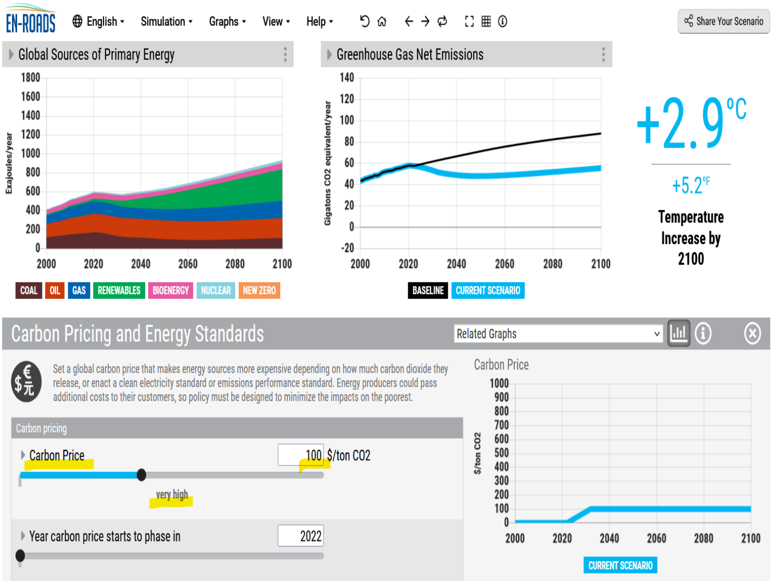
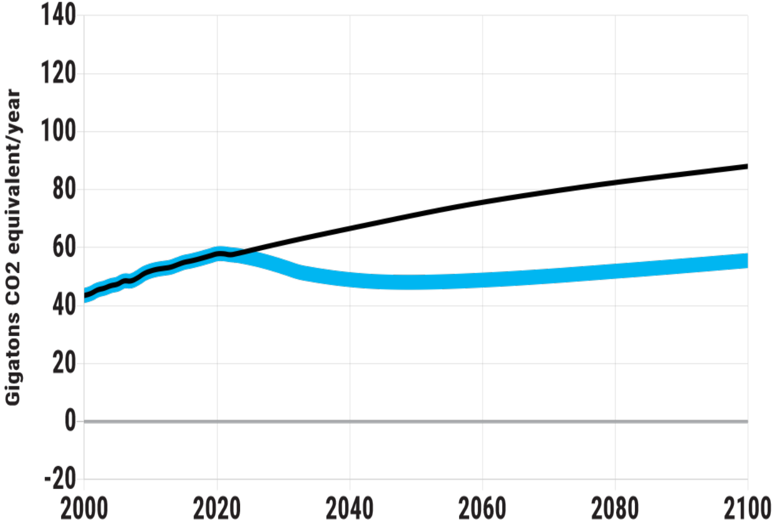
- **Impact**
  - Pronounced ↓ Coal Primary Energy Demand
  - Significant ↓ in Net CO2 Emissions
  - Sharp in ↓ Carbon Intensity of final Energy starting in the 2020s
  - ↑ of Energy Demand from Renewable Sources
  - Moderate ↓ Population Exposed to Sea Level Rise
  - Marked ↓ Air Pollution from Energy

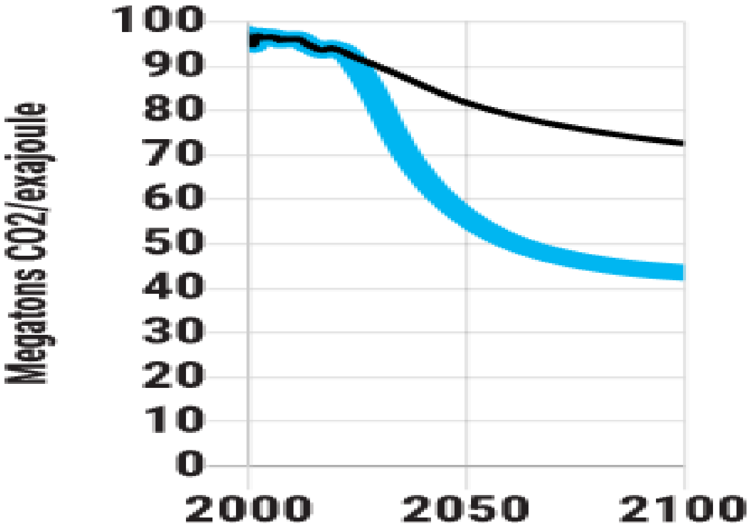
Carbon Price Simulation



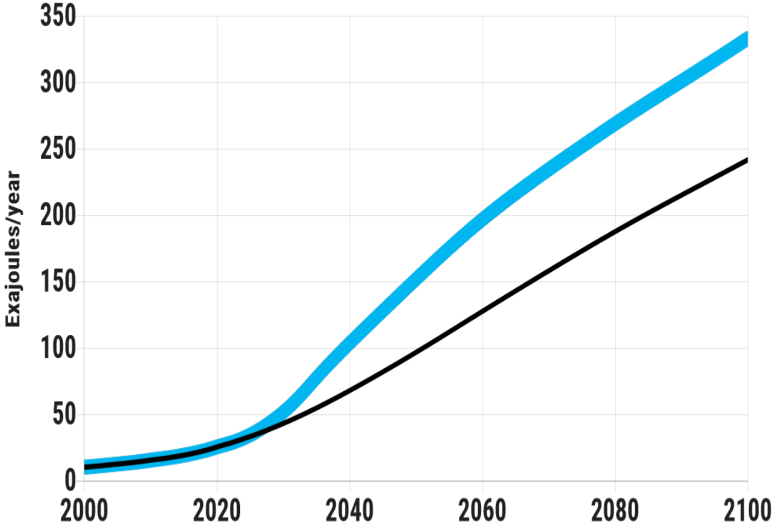
Net GHG Emissions



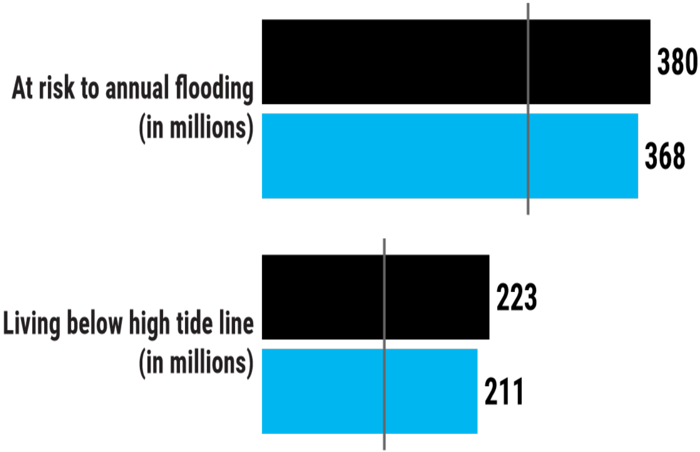
Carbon Energy Intensity



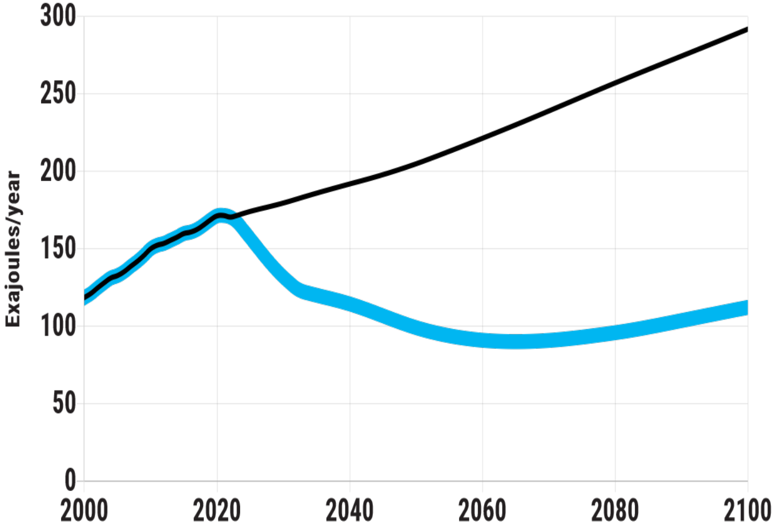
Renewables Primary Energy Demand



Population Exposed to Sea Level Rise



Coal Primary Energy Demand



Air Pollution from Energy