Real Options in Environmental Policy

Workshop on Environmental Policy Options

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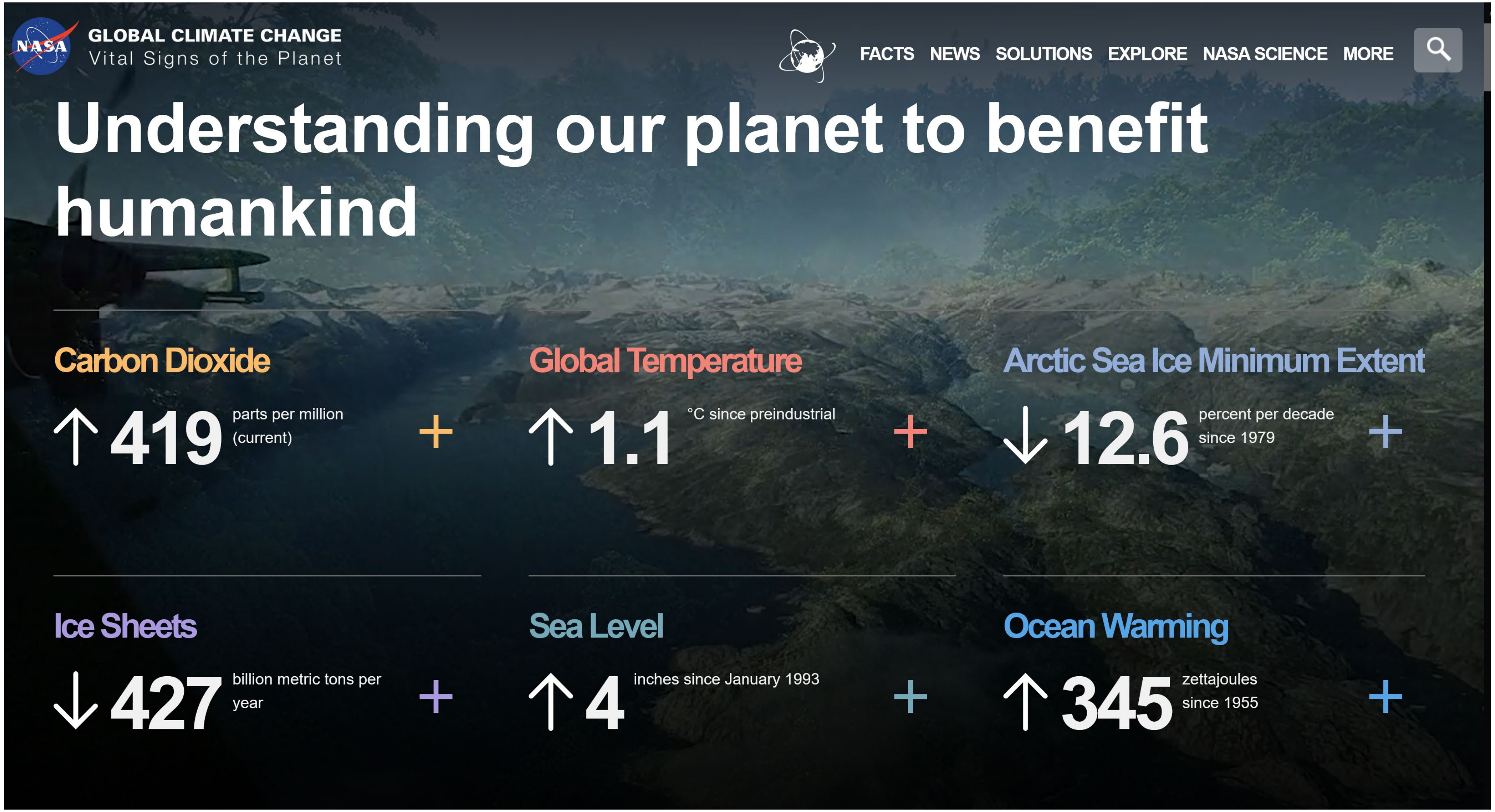
Agenda

- Climate change
- Environmental policy landscape
- Real options in environmental policy
- Literature review summary
- Case studies
  - Innovation subsidies versus consumer subsidies: A real options analysis of solar energy
  - The impact of Norwegian-Swedish green certificate scheme on investment behavior: A wind energy case study
- Conclusions

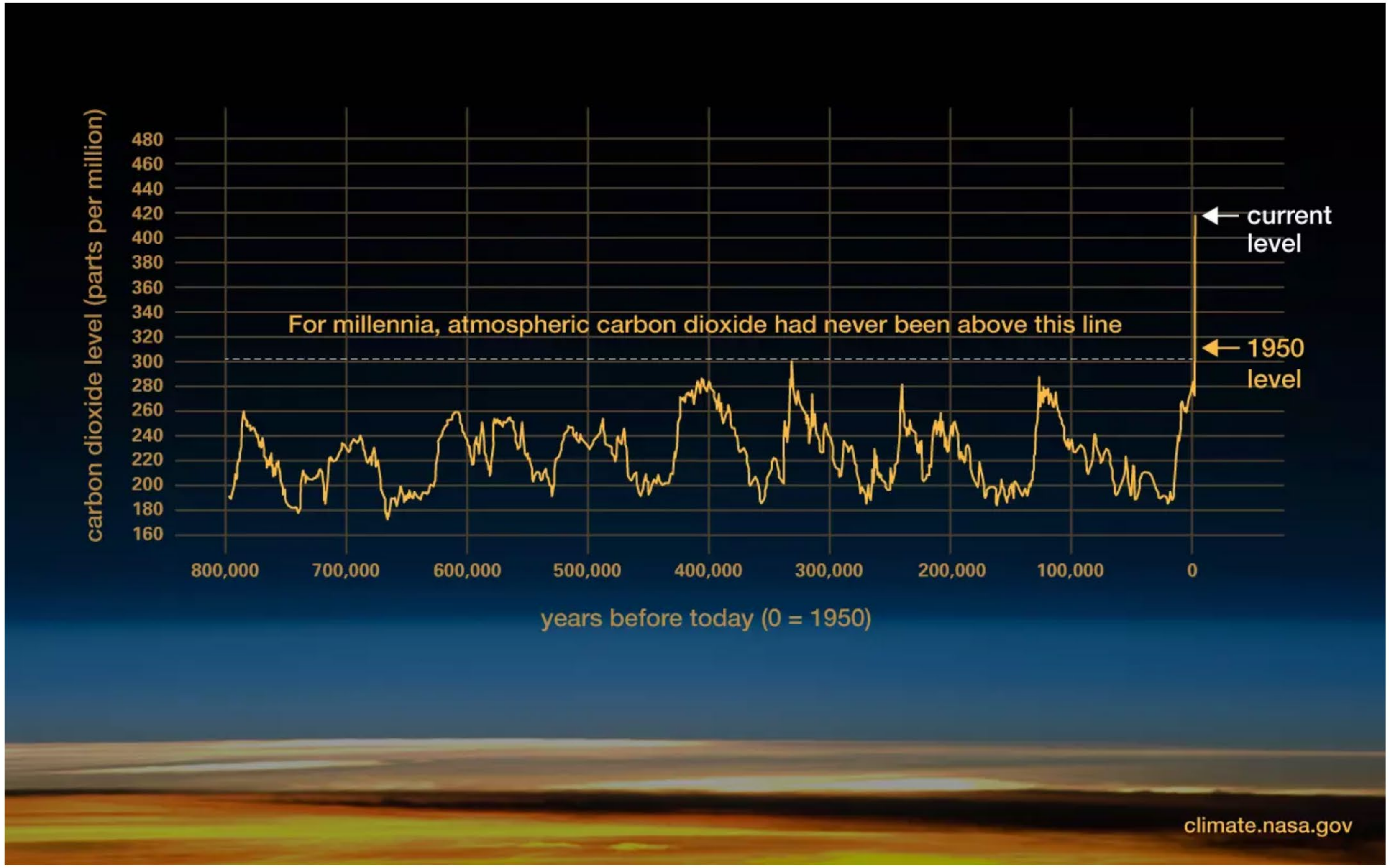
Climate Change

Climate Change



From: https://climate.nasa.gov/

Atmospheric CO_2 Levels



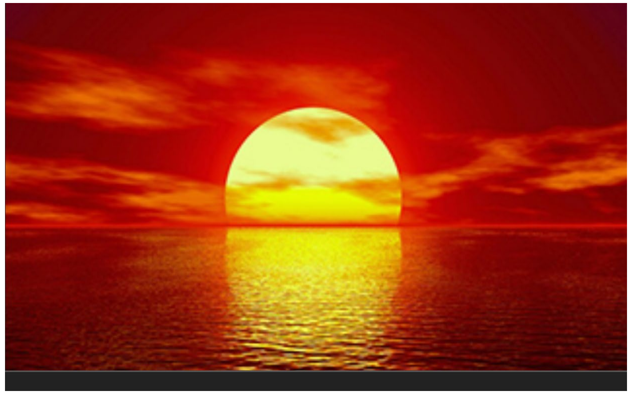
From: https://climate.nasa.gov/

Climate Change Evidence

Global temperature is rising

Ice sheets are shrinking

Oceans are getting warmer



Glaciers are retreating

Climate Change Evidence

Snow cover is decreasing

Extreme events are increasing

Sea levels are rising

Ocean acidification is increasing

https://climate.nasa.gov/

Environmental Policy Landscape

Environmental Policy History

- Earliest sewers constructed in Mohenjo-daro (Pakistan) c. 2500–1700 BCE and ancient Rome
- Ancient Greece (2300 years ago) created laws governing forest harvesting
- Feudal European societies established hunting preserves
- Paris developed Europe's first large-scale sewer system (17th century)
- Industrialization led to regulations to protect human health and natural landscapes (Yellowstone National Park – first national park, 1872)

https://www.britannica.com/topic/environmental-policy

Environmental Policy History[1] (USA)

- ERA I – Resource Use
  - 200 year period from 17th to 19th centuries
  - Laws were grounded in the anthropomorphic belief that nature and its natural resources were meant for productive human use
- ERA II – Conservation
  - Late 19th and eary 20th centuries
  - Conservation ideals surfaced as part of a progressive legal reform movement, realizing a finite supply of natural resources and conservation laws were put in place but were to be anthropomorphic, motivated by what was in the best interest for humans
- ERA III – Preservation
  - Began to appear in mid-20th century
  - Awareness that some natural resources and iconic vistas, as well as various wildlife species and historic sites, were disappearing as a result of the resource policies of the previous two eras led to laws centered around preservation but continued to be centered on anthropocentric values
- ERA IV – Protection
  - Latter half of 20th century
  - Realization that human activity was polluting and poisoning natural resources that were impacting human health and wealth, and policies began to include economic models
    - Chemicals: pesticide, mercury controls – 1950s
    - Clean Air Act (USA) – 1970
    - Clean Water Act (USA) – 1972
- *ERA V – Climate Change?*

[1] https://scholarship.law.wm.edu/cgi/viewcontent.cgi?article=1609&context=wmelpr (2014)

Climate Change Awareness

- ExxonMobil: Oil giant predicted climate change in 1970s
  (https://www.bbc.com/news/science-environment-64241994)

International Climate Change Policies

2015: COP21 Paris Agreement adopted

2010: COP16 National Adaptation Plan adopted

2001: COP7 finalized most of the operational details - set the stage for nations to ratify the Kyoto Protocol

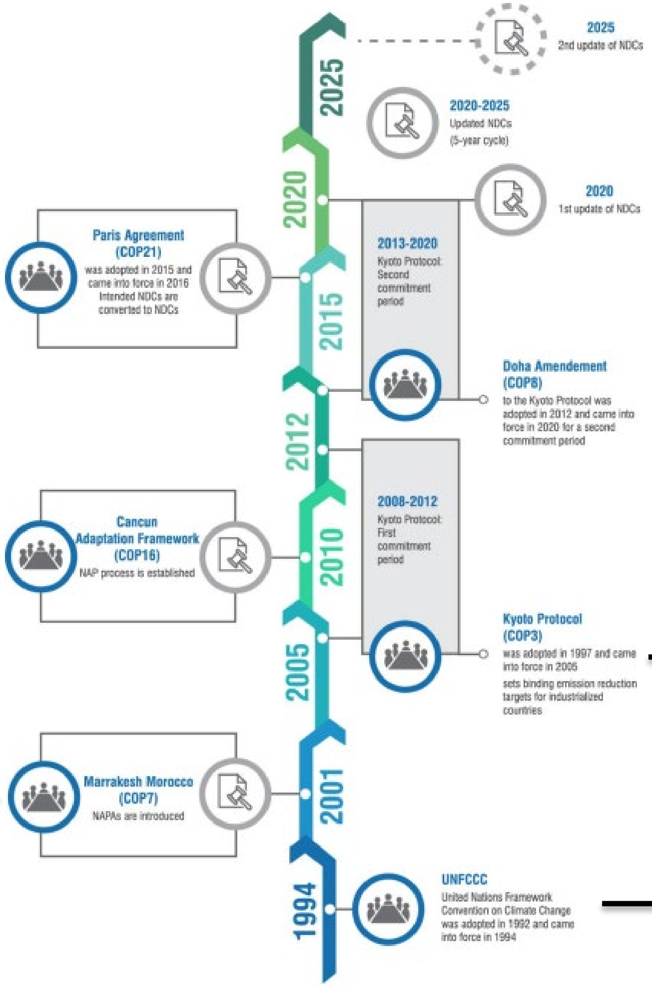


FIGURE 0.1 Timeline of major milestones of international climate-change considerations

https://ppp.worldbank.org/public-private-partnership/understand-international-climate-policy-landscape

2012: Doha Amendment, Kyoto Protocol second commitment

2005: Kyoto Protocol came into force

1994: UN Framework Convention on Climate Change (UNFCCC), international environmental agreement entered into force

Evaluation Methods in Environmental Policy

- Watkiss et al. (2015) provided a critical review and assessment of existing economic decision support tools
- ROA most useful when:
  - Large irreversible capital decisions
  - Climate risk probabilities known or good information
  - Good quality data exists for major cost/benefit components

	Approach	Summary	Examples
Traditional economic decision support	Cost-Benefit Analysis	Values all costs and benefits to society of all options, and estimates the net benefits/costs in monetary terms.	Green Book, HMT (2007) AIACC (2006).
	Cost-Effectiveness Analysis	Compares costs against effectiveness (monetary/non-monetary) to rank, then cost-curves for targets/resources.	Boyd et al. (2006)
Uncertainty framing	Iterative Risk Management	Uses iterative framework of monitoring, research, evaluation and learning to improve future strategies.	EA (2011) Haasnoot et al (2013; 2014) Watkiss et al (2013)
Economic decision making under uncertainty	Real Options Analysis	Allows economic analysis of future option value and economic benefit of waiting / information / flexibility.	Linquiti and Vonortas (2012) Tourkolias et al. (2013) Jeuland & Whittington (2013)
	Robust Decision Making	Identifies robust (rather than optimal) decisions under deep uncertainty, by testing large numbers of scenarios.	Groves & Lempert (2007) Hulme & Dessai (2009) Hallegatte et al. (2012)
	Portfolio Analysis	Economic analysis of optimal portfolio of options by trade-off between return (NPV) and uncertainty (variance).	Crowe & Parker (2008) Hunt (2009)

Flawed Modelling and the Role of Real Options

- Why Environmental Policies Fail (Laitos&Wolongevicz)[1]
  - – Flawed assumptions
  - – Inaccurate models (scientific and economic)
- Real options models can enhance policy / decision making
  - – Carbon pricing and emissions trading
  - – Renewable energy subsidies
  - – Natural resource management
  - – Infrastructure development

[1] https://scholarship.law.wm.edu/cgi/viewcontent.cgi?article=1609&context=wmelpr (2014)

Introduction: Real Option Basics

Policy Investment Opportunity

Consider a policy with social cost I: implement now (t $= 0$), or one period in the future (t $= 1$)?

A) <u>Implement Now:</u>

- Claim immediate benefit of B_0
- At t =1, claim B_{1h} (high payoff) with probability q, (assume $B_{1h} > I$), or B_{1l} (low payoff) with probability $1 - q$, (assume $B_{1h} < I$)
- $NPV_{now} = B_0 - I + \gamma(qB_{1h} + (1-q)B_{1l})$

B) <u>Implement at t=1:</u>

- Forego immediate benefit of B_0
- Option to not invest if B_{1l} is not beneficial
- $NPV_{wait} = \gamma(q(B_{1h} - I) + \cancel{(1-q)(B_{1l} - I)})$

Policy Investment Opportunity

- Policy Implementation NPV:
  - Value of option to wait: $V_0 = NPV_{wait} - NPV_{now} = I(1 - q\gamma) - B_0 - \gamma(1 - q)B_{1l}$
  - If $V_0 > 0$ then there is value to wait, i.e., if $B_{1l} < \frac{I(1-q\gamma)-B_0}{\gamma(1-q)}$
- Main Results
  - Currently unattractive projects ($NPV_{now} < 0$) may be attractive in the future
  - Lower B_{1l} leads to higher value in postponing
  - Future positive benefits may not impact decision making (the "bad" dictates)
- Other Results from Real Options Modelling
  - Competition typically increases early investment incentive
  - Incentive to invest to glean more information (value in staging investments)

Real Options in Environmental Policy

Real Options in Environmental Policy

- Real options analysis: a decision-making framework.
- *Policymakers* and *decisionmakers* can evaluate the flexibility and potential benefits associated with different policies in dynamic environments.
- Environmental policy characteristics:
  - Long-term investments
  - Considerable future uncertainty in terms of policy, costs and environmental outcomes
  - Many decisions involve irreversible actions

Real Options (Thinking) in Environmental Policy

- Timing and Flexibility
  - Allows policymakers to delay, accelerate, or revise their strategies based on evolving conditions
- Uncertainty and Learning
  - Learn from ongoing monitoring, research, and pilot projects
- Valuing Different Outcomes
  - Allows for the quantification of potential benefits of different policies
- Risk Management
  - Allows policymakers to identify and mitigate potential downside risks while maximizing the upside potential of the chosen policy option
- Stakeholder Engagement
  - Promotes stakeholder engagement and collaboration by explicitly considering the interests and preferences of various stakeholders

Irreversibilities in Environmental Policies

- 2 Types of Irreversibilities (Pindyck 2000)

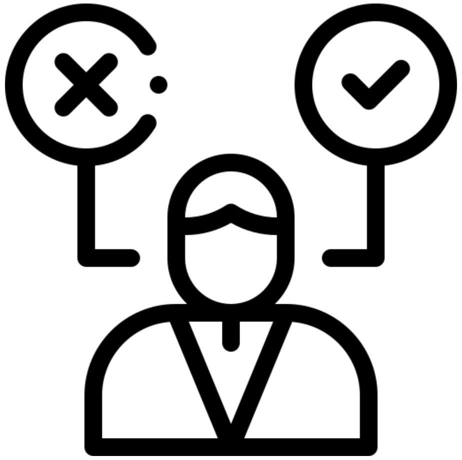
  1) Policies aimed at reducing ecological damage impose sunk costs on society (e.g., investments to reduce emissions)

  2) Policies that do not address environmental damage (e.g., global warming due to GHG emissions)

- Importance depends on:
  1) Economic uncertainty over the future costs and benefits of environmental damage and its reduction
  2) Ecological uncertainty over the evolution of the relevant ecosystem

Real Options in Policy Decisions

- Optimal Time to Invest: Invest today or hold out for more information?
  - Optimal stopping models can illustrate when to stop waiting and invest
  - Predominantly modelled through stochastic (random) processes such as Geometric Brownian motion (GBM)



Environmental Policy: Private vs Social Costs

- Policy is needed when:
  - Private preference is to wait (low waiting cost and high irreversibility)
  - High social benefit in investing now
  - Example:
    - New technology can significantly reduce ecological damage but has high initial cost
    - Government policies are implemented to tax polluters and subsidize investment

Literature Review Summary

Literature Review Summary

- Filtered papers based on:
  - "real options“ and "environmental policy” keywords
  - Published 2016 or later
  - Peer reviewed articles
- Total: 24 (plus 2 review papers)
  - 4 non-model opinion papers
  - 2 empirical-based papers
  - 18 model-based papers

Summary of 24 Journal Articles

- Application Country
  - Not specific: 6
  - Brazil: 1
  - China: 6
  - Denmark: 1
  - India: 1
  - Ghana: 1
  - Indonesia: 2
  - Norway: 1 (shared w/ Sweden)
  - Russia: 1
  - Sweden: 1 (shared w/ Norway)
  - Russia: 1
  - UAE: 1
  - USA: 4
- Environmental Target
  - Energy related: 17
  - Land use: 4
  - General: 3

Summary of 24 Journal Articles

- Numerical Models:
  - Lattice: 6
  - Least squares Monte Carlo (LSMC): 5
  - Optimal investment in infinite time: 5
  - Market Asset Disclaimer (MAD): 1
  - NPV with simulation: 1
- Almost all models used geometric Brownian motion (GBM) with one GBM and MR

Summary of 24 Journal Articles

- All articles concluded that real options analysis either led to better decision making or provided other advantages

- Articles varied in mathematical complexity

- In a few cases, the real options formulation was suspect

Application I

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

ELSEVIER

ENERGY POLICY

Innovation subsidies versus consumer subsidies: A real options analysis of solar energy ☆

Kiran Torani, Gordon Rausser, David Zilberman *

Department of Agricultural and Resource Economics, U.C. Berkeley, 230 Giannini Hall, CA 94720, USA

H I G H L I G H T S

- Stochastic dynamic model of solar PV adoption under two sources of uncertainty.
- Simulation across electricity prices, technical change, subsidies and CO_2 taxes.
- Rate of technical change indicates shift to solar in 25–28 years without incentives.
- Modest impact of consumer subsidies and CO_2 taxes (up to \$150/ton CO_2) in adoption.
- R&D support/further technological change is the main driver of adoption of solar.

Application I

- Question: how to transition to solar energy and which policies are most effective in accelerating adoption?
- Uncertainties: electricity price, photovoltaic cell cost
- Model: two-factor optimal stopping problem, empirical analysis using market US data.

Application I

- Main conclusions:
  - Displacement of incumbent technologies and a widespread shift towards solar PV in under 30 years – can occur even *without consumer incentives.*
  - Further technological change is the crucial determinant and main driver of adoption.
- Policy implication:
  - Implement incentives related to R&D investment rather than consumer subsidies

Application II

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

The impact of Norwegian-Swedish green certificate scheme on investment behavior: A wind energy case study

Fredrik Finjord, Verena Hagspiel, Maria Lavrutich*, Marius Tangen

Department of Industrial Economics and Technology Management, Norwegian University of Science and Technology, 7491 Trondheim, Norway

Application II

- Question: how will green certificate subsidy scheme effect the value of renewable energy investments?
- A wind energy case study:
  - **Norway**: invest before a project deadline to receive green certificates.
  - **Sweden**: no deadline, but certificates are received for a shorter duration for later investments
- Uncertainties: electricity and green certificate price

Application II

- Model: two-factor optimal stopping problem with finite time horizon: Least Squares Monte Carlo. Market data for Norway and Sweden were incorporated
- Main conclusions:
  - Deadlines lower option values and investment thresholds – larger effect for shorter deadlines
  - Investment thresholds of both investors decline with certificate duration
  - At current price levels, it is not optimal for either investor to invest before the Norwegian deadline

Application II

- Policy implications:
  - Firms' behavior is affected by market uncertainty and by their investment timing flexibility.
  - Failing to consider these effects in policy decisions can jeopardize the intentions.

Conclusions

- Especially in the context of climate change, ROA can help in the implementation of better environmental policies
  – Negative (to the environment) private behaviour can be identified
  – Social benefit can be enhanced
- Many ROA papers continue to be published related to environmental policy providing tools that can be utilized by policy makers
- Real options models can help enhance real options thinking, stakeholder engagement