

Economics of Climate Change

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Climate Change Questions for Economists

- How sharply should countries reduce GHG emissions?
- What should be the time profile for emissions reductions?
- How should the reductions be distributed across sectors, industries and countries?
- What policies will be most efficient to reduce emissions?
- Who should pay? How should costs be distributed between rich and poor households or nations?



Overview

- Using economics in Climate Policy analysis:
 - Cost-benefit analysis
 - Costs
 - Benefits
- Mitigation Policy
 - Justification: market failures
- Categories of policy :
 - Command and control
 - Information
 - Economic Instruments
- Irish policy situation
- Resources



Economic Analysis of Climate Change

How much emissions should we mitigate? Which policy measure?

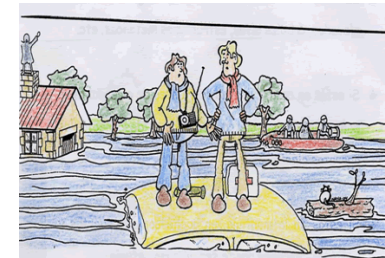
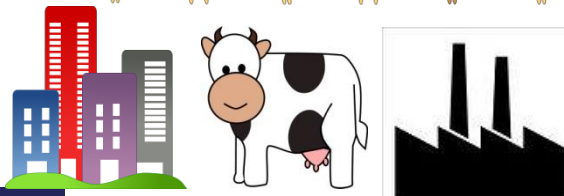
Compare
economic cost of
climate change
mitigation....



...with future
ecological benefits



Reduction
of GHG
emissions



Choosing Emissions Targets

- “The choice of a stabilization target shapes much of the rest of policy analysis and discussion, because it carries strong implications for the permissible flow of emissions, and thus for emissions reductions targets.”
- “The reduction targets, in turn, shape the pricing and technology policies.”
- Targets can be set in terms of stabilisation concentration or GHG emissions – latter more common

Stern (2008) The Economics of Climate Change, AER P&P.



Optimal GHG Emissions Reduction: Benefit-cost analysis (1)

- Societal Benefit-Cost analysis needed to establish optimal emissions reduction
- Based on concept of social welfare (W)
- In estimating welfare, we maximise net societal gain $G(E)$ as proxy for welfare
- $\text{Max } G(E) = B(E) - C(E)$
 - $B(E)$ = Benefit of emissions reduction = Avoided damage costs + ancillary benefits
 - $C(E)$ = Cost of emissions reduction

$$\frac{\delta G}{\delta E} = 0 \Leftrightarrow \frac{\delta B}{\delta E} - \frac{\delta C}{\delta E} = 0 \Rightarrow \frac{\delta B}{\delta E} = \frac{\delta C}{\delta E} = \frac{\delta D}{\delta E} \quad \text{or } \text{MC}=\text{MB}$$



Over time: Benefit-cost analysis (2)

- Climate change is a dynamic intertemporal problem
- Maximise the value of the gains over time
- Assume the benefits are instantaneous -> benefits at time t depend only on emissions at time t .
- Optimisation equation becomes:

$$\max \sum_t \frac{G}{(1+r)^t} = \sum_t \frac{D_t(E_t, E_{t-1}, \dots, E_t) - C_t(E_t)}{(1+r)^t} = NPV_t$$

Where r = discount rate

- If $NPV > 0 \Rightarrow$ policy is welfare enhancing
- In policy comparison, if $NPV_1 > NPV_2$, then Policy 1 is more welfare enhancing



Class example

- Consider two policies and a discount rate of 5%
- Estimate NPV of A and B:
- Which policy should you choose?

	Net Benefits (in \$)			
Year	0	1	2	3
Policy A	-30	20	20	20
Policy B	-30	10	10	10

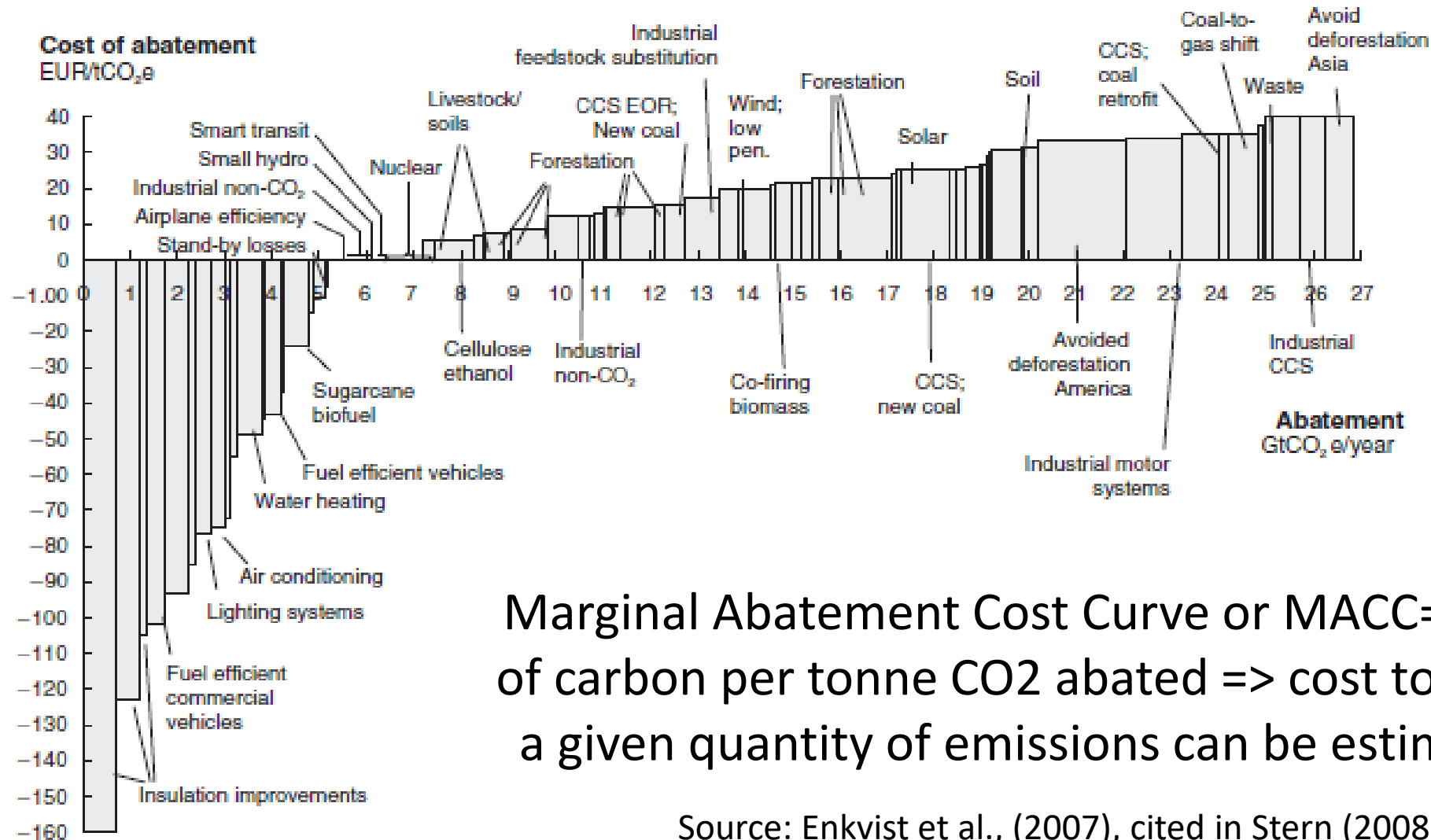
A=\$24.46

B=-\$2.77



Estimating the costs and benefits

Costs of mitigation – the famous MACC!



Marginal Abatement Cost Curve or MACC= Price of carbon per tonne CO₂ abated => cost to abate a given quantity of emissions can be estimated

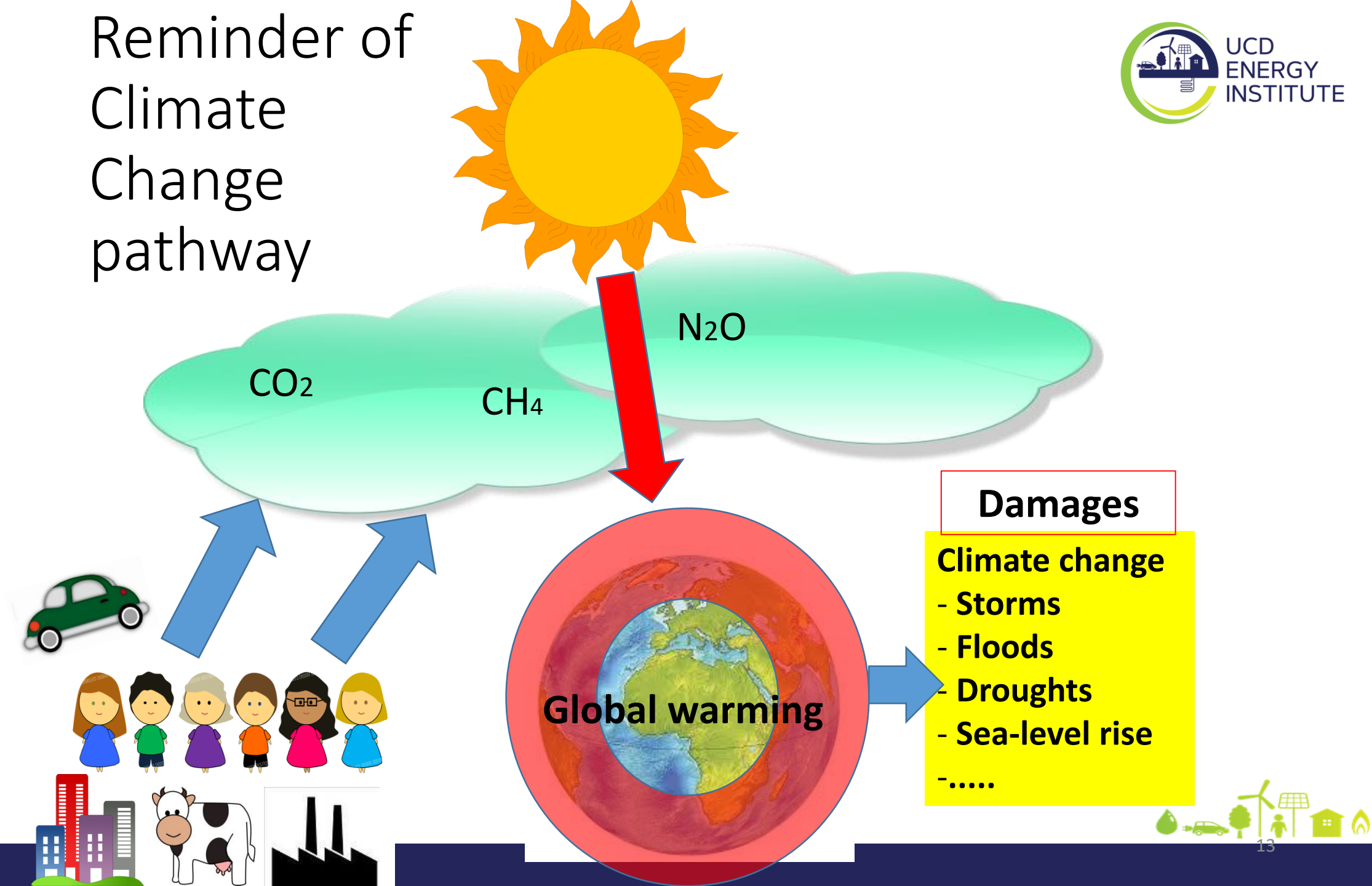
Source: Enkvist et al., (2007), cited in Stern (2008)



Estimates of the Benefits of Climate Change mitigation

- If we want to measure the benefits of climate change policy we need to estimate the avoided damages of climate change.
- They are difficult to calculate.
- **Why?**

Reminder of Climate Change pathway



Observed climate change impacts



- Physical systems
 - Glaciers, snow ice and permafrost
 - Rivers, lakes, floods, and drought
 - Coastal erosion and sea level effects
- Biological systems
 - Terrestrial ecosystems
 - Wildlife
 - Marine ecosystems
- Human and managed systems
 - Food protection
 - Livelihoods, health, and/or economics



Climate Change impacts

- **Developed countries**

- Small predicted impacts – sometimes positives.

- **Developing countries**

- More vulnerable
- Likely to suffer more adverse impacts.





Confidence in attribution to climate change



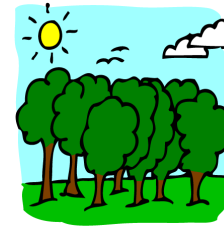
Observed impacts attributed to climate change for

<p>Physical systems</p> <ul style="list-style-type: none"> Glaciers, snow, ice, and/or permafrost Rivers, lakes, floods, and/or drought Coastal erosion and/or sea level effects 		<p>Biological systems</p> <ul style="list-style-type: none"> Terrestrial ecosystems Wildfire Marine ecosystems 		<p>Human and managed systems</p> <ul style="list-style-type: none"> Food production Livelihoods, health, and/or economics 		<p>Regional-scale impacts</p>
<p>Outlined symbols = Minor contribution of climate change Filled symbols = Major contribution of climate change</p>						



Estimates of the Damage Costs of Climate Change

- Effects considered by Tol, 2002:
 - Agriculture
 - Forestry
 - Sea level
 - Human health
 - Natural ecosystem
 - Water resources
 - Energy consumption



Attributes of Climate Change

- Uncertainty
- Ethics and distribution effects



Discounting

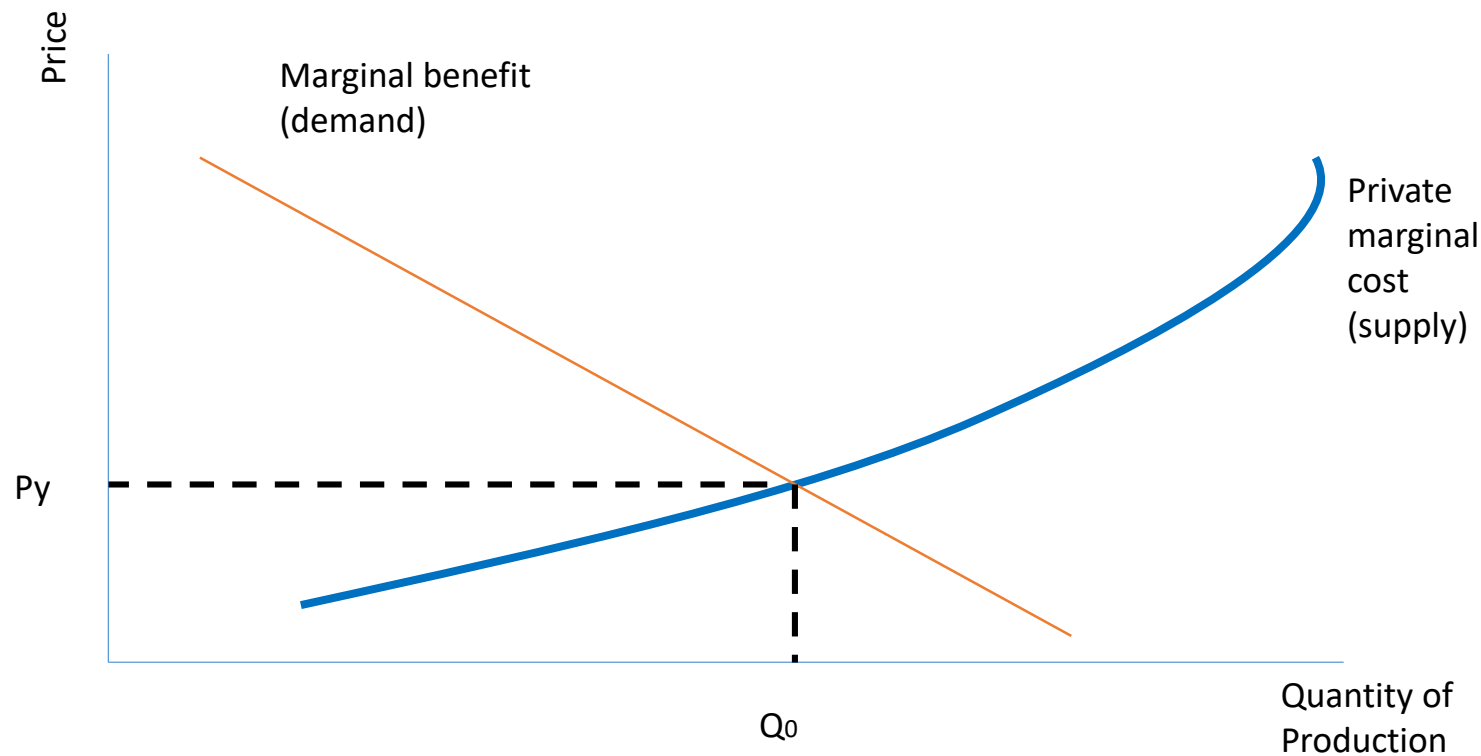
- Describes the valuation of future outcomes (V) (damages, costs, benefits, utility values) in present day terms
- Discount factor D : Gives the value of one unit in the future (generally in one year) in present value terms
- Discount rate r : Gives the rate at which future value is discounted
- It holds $D = \frac{1}{1+r}$ and
- $PV = V * D^n$ (n = number of years)
- Stern report recommended r close to zero, disputed



Climate policy: do we need it?

Can the market deliver the emissions reduction?

- Market demand and supply curves for emissions considering firm costs only
- Optimal level of production when $MC = MB$



The competitive equilibrium is P_y and Q_0 :
At $MPC = MPB$

Externalities in the Energy Sector

ARGUMENTS AGAINST-



Joahler 2011 GREENBAY PRESS GAZETTE



Negative environmental externality

- Negative externalities create a divergence between private and social costs equal to the ***external cost***.
- Problem: suppliers (ex: airlines) have no incentive to consider the external cost.
- Market forces generate an equilibrium production level and price associated with private costs rather than social costs.

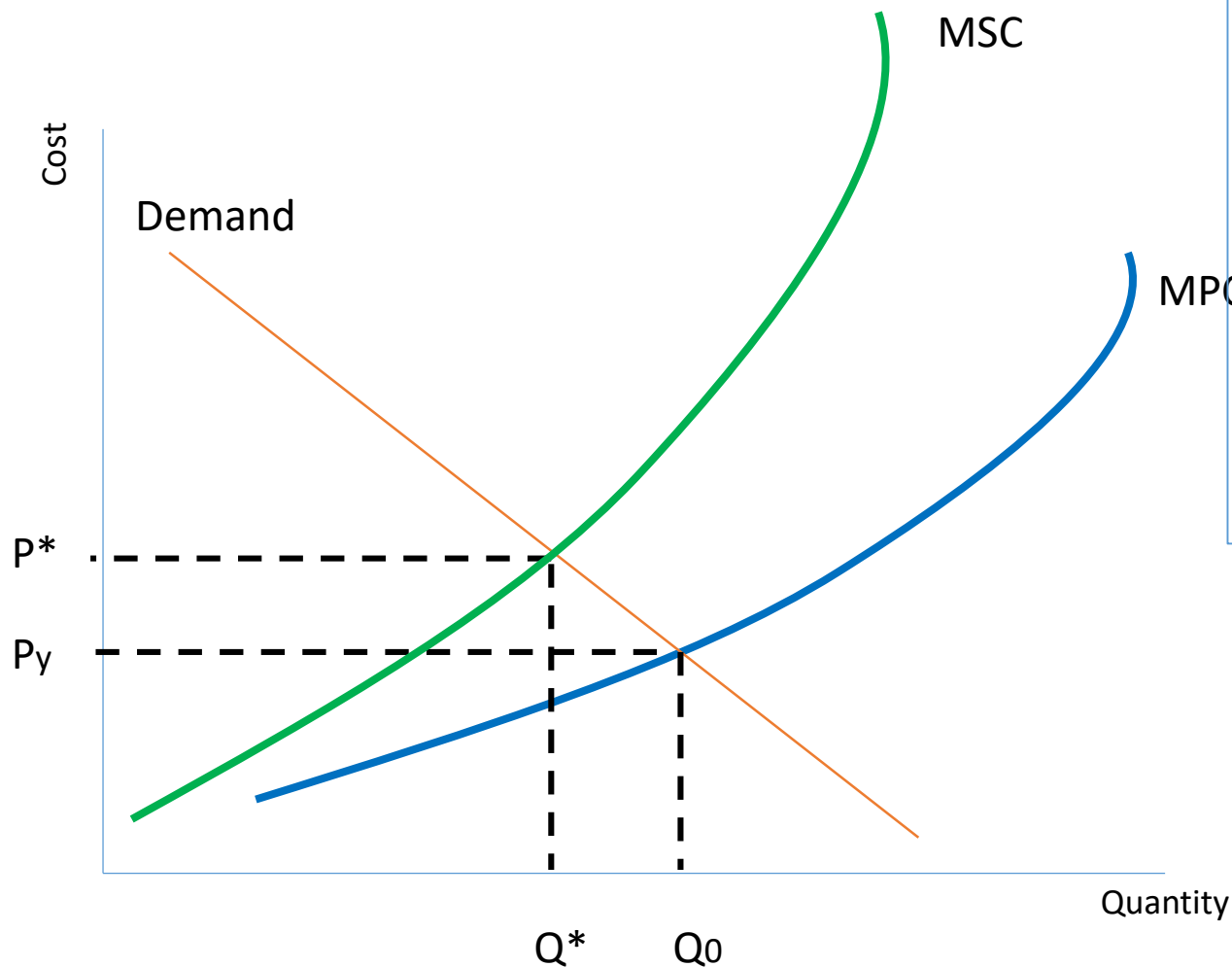
→ **Competitive solution is inefficient**



Source: S. Haller



In the presence of market failures...



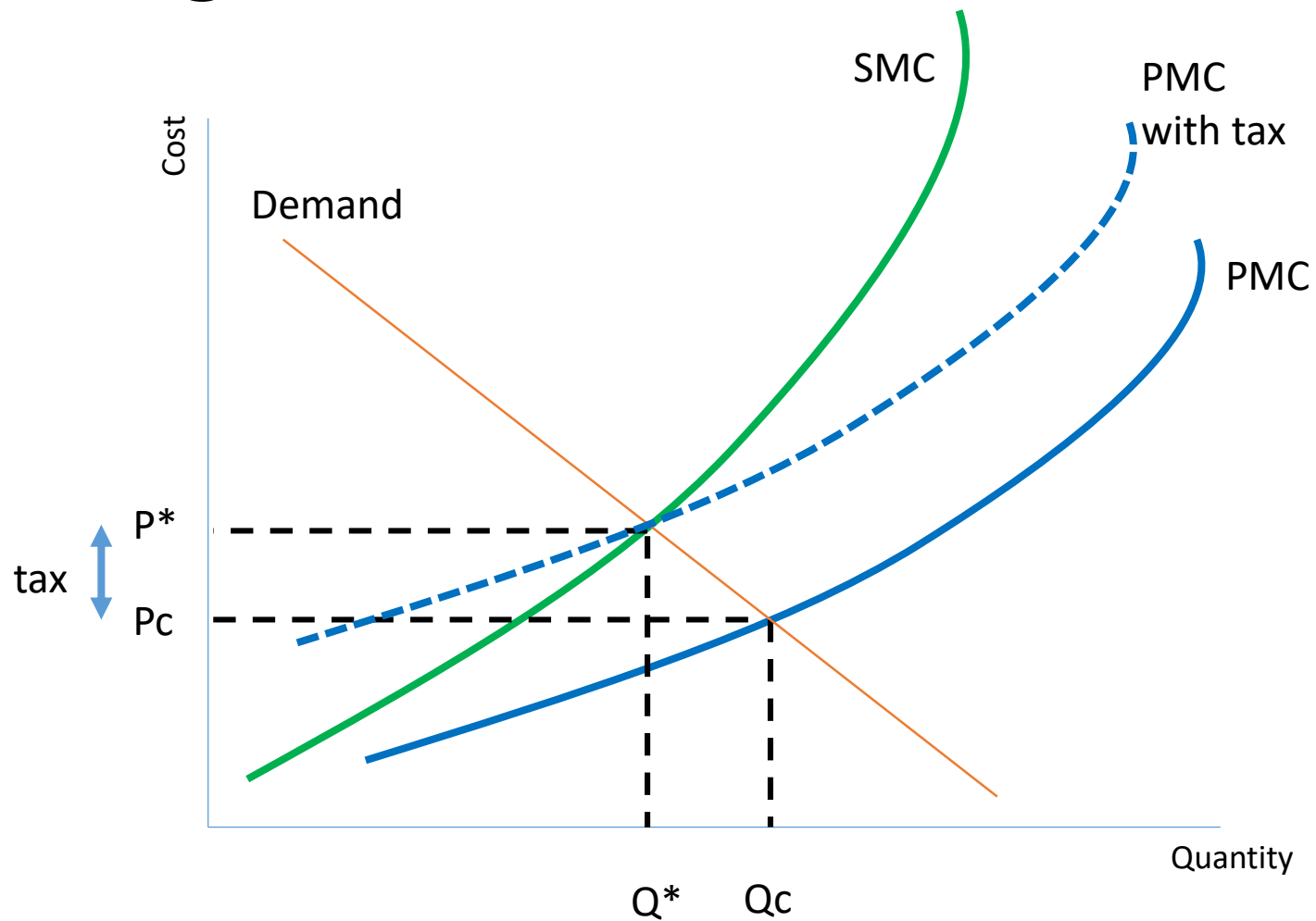
The presence of market failures means that the true cost of emissions is illustrated by the marginal social cost (MSC) of emissions.

The efficient equilibrium is at P^* and Q^* :

$$MSC = MSB$$

$$\Rightarrow MPC + MEC = MPB + MEB$$

Correcting externalities with taxes



The cost of the externality can be added as a (carbon) tax on the firm. This shifts the marginal cost curve to the left to reflect the social marginal cost of emissions.



Dealing with Externalities

- Pigou approach:
 - When the marginal social cost is not equal to the marginal private cost => charge a (Pigovian) tax equal to the difference, ie the marginal damages or marginal external cost
 - The polluter pays and externalities are internalised
- Coase approach:
 - An efficient outcome can be achieved by granting property rights to one party and one party compensating the other;
 - Marginal analysis does not always lead to the right conclusions
 - May not be equitable

Choosing Policy Instruments

Policy Instruments: categories

- Command and control – quantity-based policies
- Information measures
- Economic instruments – price-based policies



Book by Bemelmans-Videc et al. (2003)



"This is their new big carrot and stick method."

df1988-1527

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Classwork: Name climate policy instruments

	Power	Industry	Transport	Buildings
Command and control				
Economic instruments				
Information and engagement				

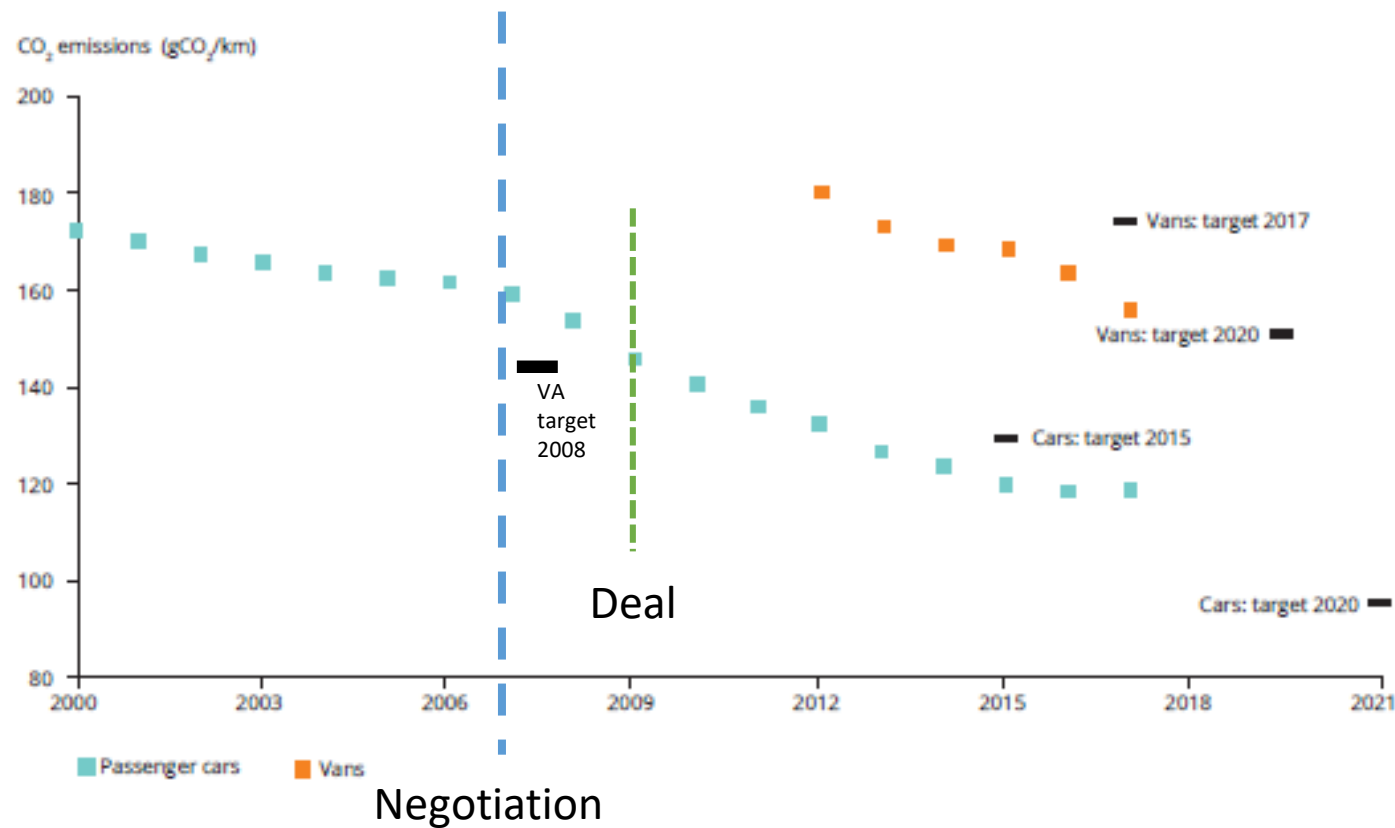


Command-and-control

- Market failure addressed: split incentives and imperfect information
- Characteristics: regulatory target set specifying environmental performance, e.g. emissions limits, technical characteristics, e.g. minimum performance standard
- Strengths: relatively easy to understand and administer, no subsidy from public budget
- Weaknesses: often inefficient, i.e. not least cost, enforcement needed, risk of regulatory capture, policymaker technical capability important.
- Examples: building codes, EU car CO₂ emissions regulation, EU energy efficiency regulations on electric appliances

Example: Passenger car regulation

Average CO₂ emissions: historical development and targets EU-28



Source: EEA, 2018



Information measures

- Overcome market failures relating to imperfect information
- Can be combined with other policy instruments such as incentives and regulation
- Need to raise awareness among public and relevant sector
- Usually provide information in the form of labels: BER in Ireland, CO2 labels on cars, energy efficiency of white goods
- Design of labels important
- Allow sufficient time in advance of implementation to ensure trained professionals where certification is needed
- Regular checking of assessors and enforcement needed to ensure credibility

Example Information measures: Buildings rating labelling Ireland and Portugal

Building Energy Rating (BER) DEAP Version X.Y

BER for the building detailed below is: **C1**

Name of House, Street Name One, Street Name Two, Town name One, Town Name Two, County name One, County name Two,

BER Number: XXXXXXXXXX
Date of Issue: Day Month Year
Valid Until: Day Month Year
BER Assessor No.: XXXX
Assessor Company No.: XXXX

The Building Energy Rating (BER) is an indication of the energy performance of this dwelling. It covers energy use for space heating, water heating, ventilation and lighting, calculated on the basis of standard occupancy. It is expressed as primary energy use per unit floor area per year (kWh/m²/yr). 'A' rated properties are the most energy efficient and will tend to have the lowest energy bills.

Building Energy Rating kWh/m²/yr MOST EFFICIENT

<25	A1
>25	A2
>50	A3
>75	B1
>100	B2
>125	B3
>150	C1
>175	C2
>200	C3
>225	D1
>260	D2
>300	E1
>340	E2
>380	F
>450	G

Carbon Dioxide (CO₂) Emissions Indicator kgCO₂/m²/yr

BEST 0

Calculated annual CO₂ emissions XXX kgCO₂/m²/yr

WORST >120

The less CO₂ produced, the less the dwelling contributes to global warming.

IMPORTANT: This BER is calculated on the basis of data provided to and by the BER Assessor, and using the version of the assessment software quoted above. A future BER assigned to this dwelling may be different, as a result of changes to the dwelling or to the assessment software.

Certificação Energética e Ar Interior EDIFÍCIOS Nº CER 1234567/2007

CERTIFICADO DE DESEMPENHO ENERGÉTICO E DA QUALIDADE DO AR INTERIOR

TIPO DE EDIFÍCIO: EDIFÍCIO HABITAÇÃO UNIFAMILIAR / FRACÇÃO AUTÓNOMA DE EDIF. MULTIFAMILIAR

Morada / Situação: _____
Localidade _____ Freguesia _____
Concelho _____ Região _____
Data de emissão do certificado _____ Validade do certificado _____
Nome do perito qualif. _____ Número do perito qualif. _____
Imóvel descrito na _____ Conservatória do Registo Predial de _____
sob o nº _____ Art. matricial nº _____ Fracção autón. _____

Este certificado resulta de uma verificação elaborada ao edifício ou fracção autónoma, por um perito devidamente qualificado para o efeito, em relação aos requisitos previstos no Regulamento das Características de Comportamento Térmico dos Edifícios (RCCTE, Decreto-Lei 80/2006 de 4 de Abril), classificando o imóvel em relação ao seu desempenho energético. Este certificado permite identificar possíveis medidas de melhoria de desempenho aplicáveis à fracção autónoma ou edifício, suas partes e respectivos sistemas energéticos e ventilação, que no seu conjunto melhorem o desempenho energético e a qualidade do ar interior.

1. ETIQUETA DE DESEMPENHO ENERGÉTICO

INDICADORES DE DESEMPENHO

Necessidades anuais globais estimadas de energia primária para climatização e águas quentes _____ kgep/m².ano

Valor limite máximo regulamentar para as necessidades anuais globais de energia primária para climatização e águas quentes (limite inferior da classe E*) _____ kgep/m².ano

Emissões anuais de gases de efeito estufa associadas à energia primária para climatização e águas quentes _____ toneladas de CO₂ equivalentes por ano

CLASSE ENERGÉTICA

A	A*
B	B
C	C
D	D
E	E
F	F
G	G

2. DESAGREGAÇÃO DAS NECESSIDADES NOMINAIS DE ENERGIA ÚTIL

Necessidades nominais de energia útil para...	Valor estimado para as condições de conforto térmico de referência	Valor limite regulamentar para as necessidades anuais
Aquecimento	kWh/m ² .ano	kWh/m ² .ano
Arrefecimento	kWh/m ² .ano	kWh/m ² .ano
Preparação das águas quentes sanitárias	kWh/m ² .ano	kWh/m ² .ano

NOTAS EXPLICATIVAS

As necessidades nominais de energia útil correspondem a uma previsão da quantidade de energia que terá de ser consumida por m² de área útil do edifício ou fracção autónoma para manter o edifício nas condições de conforto térmico de referência e para preparação das águas quentes sanitárias necessárias aos ocupantes. Os valores foram calculados para condições convencionais de utilização, admitidas como idênticas para todos os edifícios, de forma a permitir comparações objetivas entre diferentes imóveis. Os consumos reais podem variar bastante dos indicados e dependem das atitudes e padrões de comportamento dos utilizadores.

As necessidades anuais globais de energia primária (estimadas a valor limite) resultam da conversão das necessidades nominais de energia útil em diagramas equivalentes de peritagem por unidade (kgpe) de área útil do edifício, mediante aplicação de fatores de conversão específicos para cada formato) de energia utilizada) (0,200 kgpe/kWh para eletricidade e 0,086 kgpe/kWh para combustíveis sólidos, líquido ou gasosos) e tendo em consideração a eficiência dos sistemas adotados ou, na sua inexistência, sistemas convencionais do referencial.

As emissões de CO₂ equivalente traduzem a quantidade anual estimada de gases de efeito estufa que podem ser libertadas em resultado da conversão de uma quantidade de energia primária igual às respectivas necessidades anuais globais estimadas para o edifício, usando o fator de conversão de 0,0112 toneladas equivalentes de CO₂ por kgpe.

A classe energética resulta do rácio entre as necessidades anuais globais estimadas e as máximas admissíveis de energia primária para aquecimento, arrefecimento e para preparação de águas quentes sanitárias no edifício ou fracção autónoma. O melhor desempenho corresponde à classe A*, seguido das classes A, B, C e seguintes, até à classe G de pior desempenho. Os edifícios com energia ou autoaproveitamento de conservação passiva e 4 de julho de 2006 podem ter classe energética igual ou superior a F*. Para mais informações sobre o desempenho energético, sobre a qualidade do ar interior e sobre a classificação energética de edifícios, consulte www.dggeg.pt

Edição 2014
Direção Nacional de DCE
Direção Geral de Energia e Geologia
AGÊNCIA PORTUGUESA DO AMBIENTE



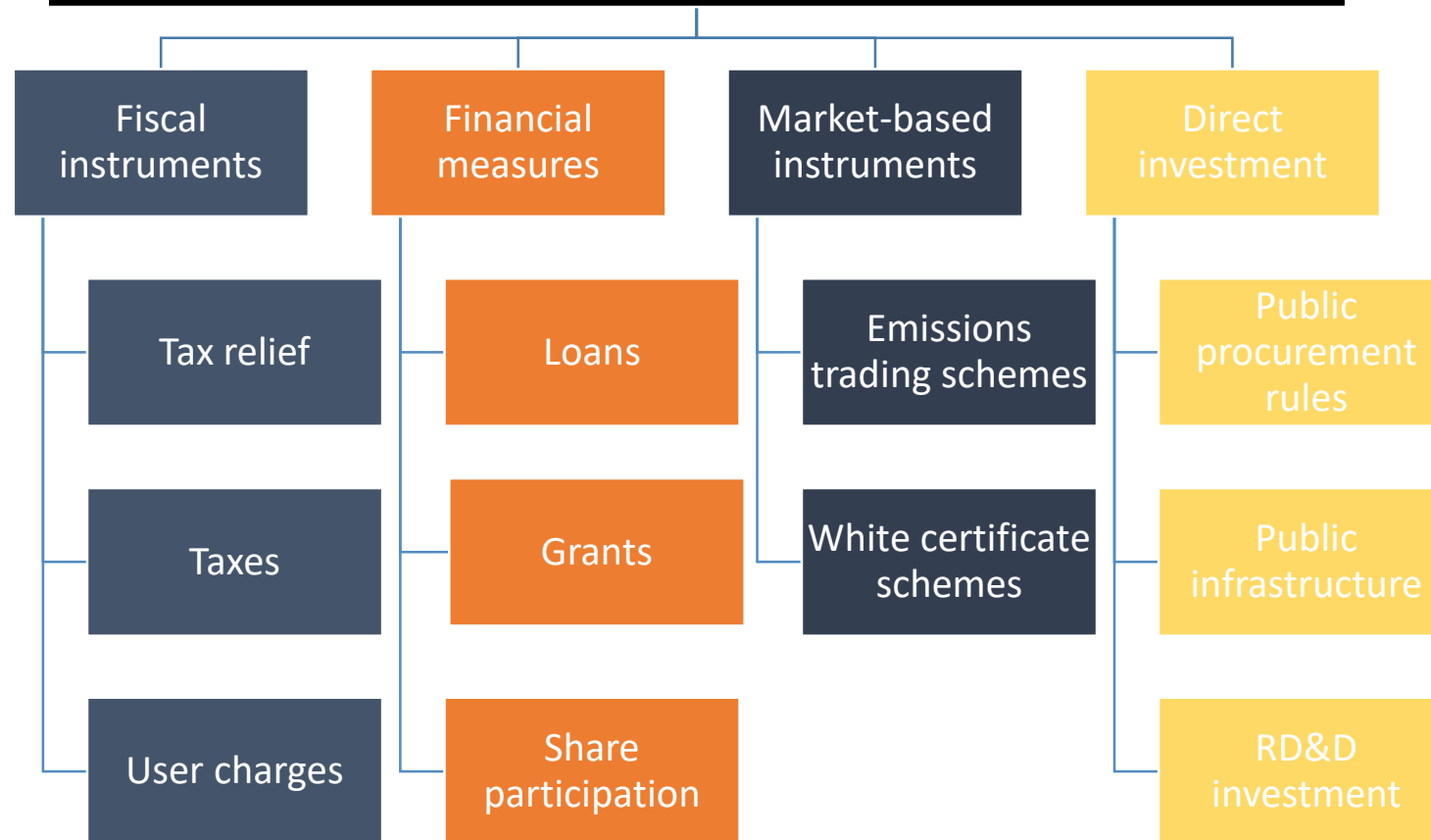
Economic policy instruments (Pricing)

- Economic instruments impose a price on goods equal to the marginal external cost of their use (marginal environmental damage cost)
- This may imply a subsidy for products that are public goods or environmental goods
- Strengths of economic instruments:
 - Cover cost of environmental damage
 - Provide incentive effects for responsible consumption
 - Raise revenue
- Weaknesses:
 - Uncertainty in damage costs and abatement costs means that prices can be difficult to set
 - Asymmetric information
 - May lead to distributional inequity

“A sufficiently high carbon price also promotes investment in clean, low-carbon technologies.” European Commission.



Economic or market-based policy instruments



Economic instruments for clean energy in power, industry, transport and buildings

Power sector
<ul style="list-style-type: none">• Emissions trading• Subsidies for renewables• Fuel taxes

Industry
<ul style="list-style-type: none">• Tax relief• Audit support• CO₂ emissions trading• Energy management support• R&D incentives• Energy prices• Carbon taxes• 3rd party finance and ESCOs

Transport
<ul style="list-style-type: none">• Vehicle tax incentives• Advanced vehicle subsidies• Fuel taxes• User charges• Infrastructure investment• CO₂ emissions trading• Carbon taxes

Buildings
<ul style="list-style-type: none">• Grants for EE equipment• Loans and grants for refurbishment• Direct investment in social housing• Tax relief• Energy prices• Carbon taxes• 3rd party finance and ESCOs

Carbon tax is most direct example!

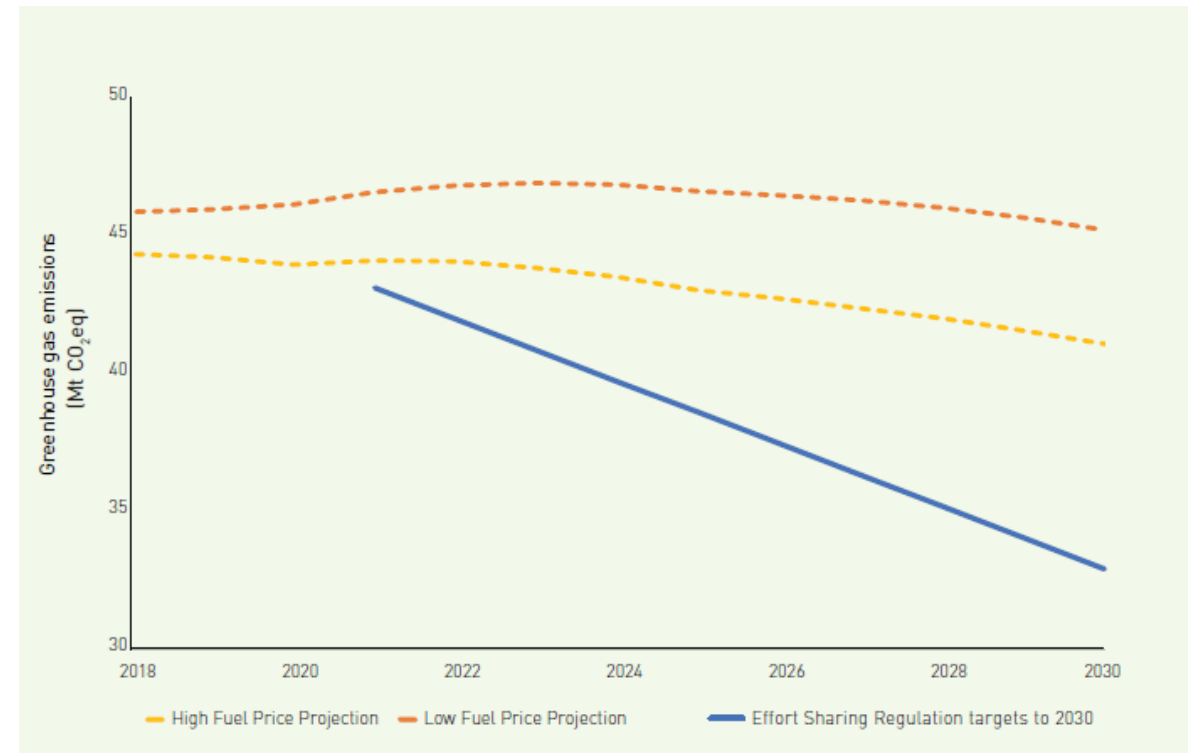


Criteria for selection of Policy Instruments

- Cost-effectiveness (static efficiency)
- Long-run effects
- Dynamic efficiency
- Feasibility
- Ancillary benefits
- Equity
- Dependability
- Flexibility
- Information and uncertainty

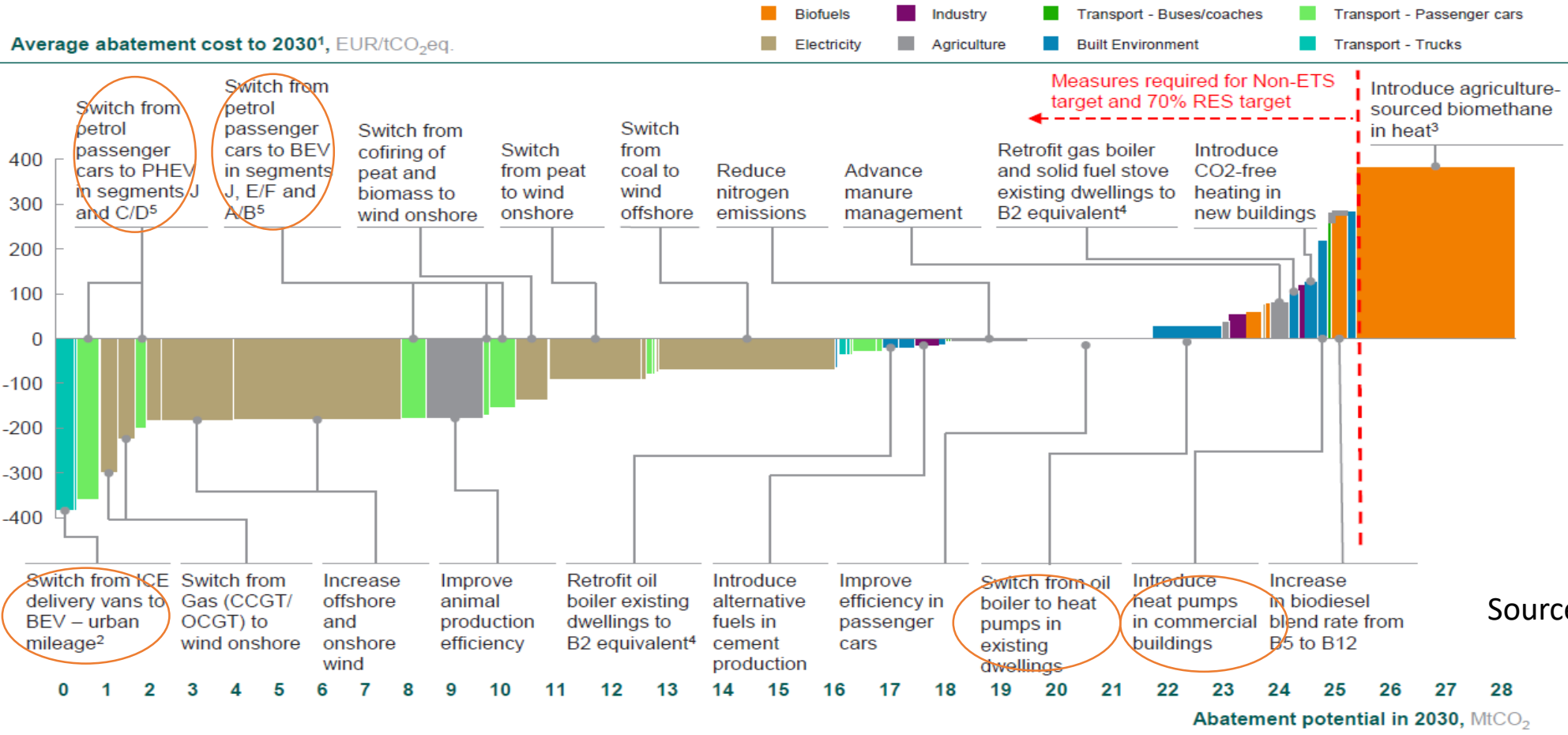
Ireland CO₂ emissions mitigation strategy

- *National Policy Position on Climate Action and Low Carbon Development:* 80% reduction in CO₂ emissions by 2050 (moving to net zero carbon)
- Ireland will not meet 2020 Renewable energy or CO₂ emissions targets
- Climate Action Plan launched 21st June 2019



Climate Action Plan: Marginal Abatement Cost Curve

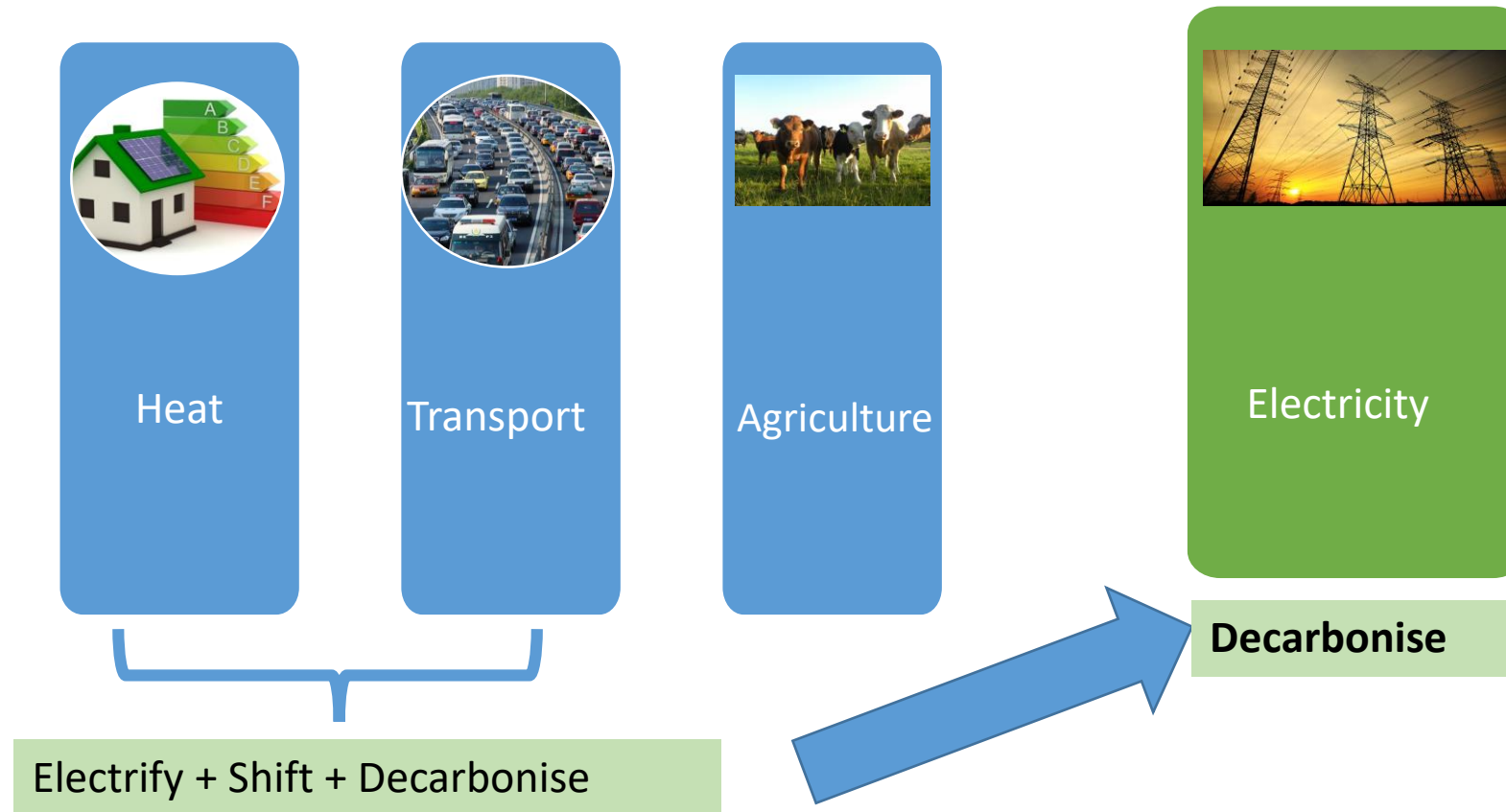
Electrification of heat and transport, 70% RES-E key measures



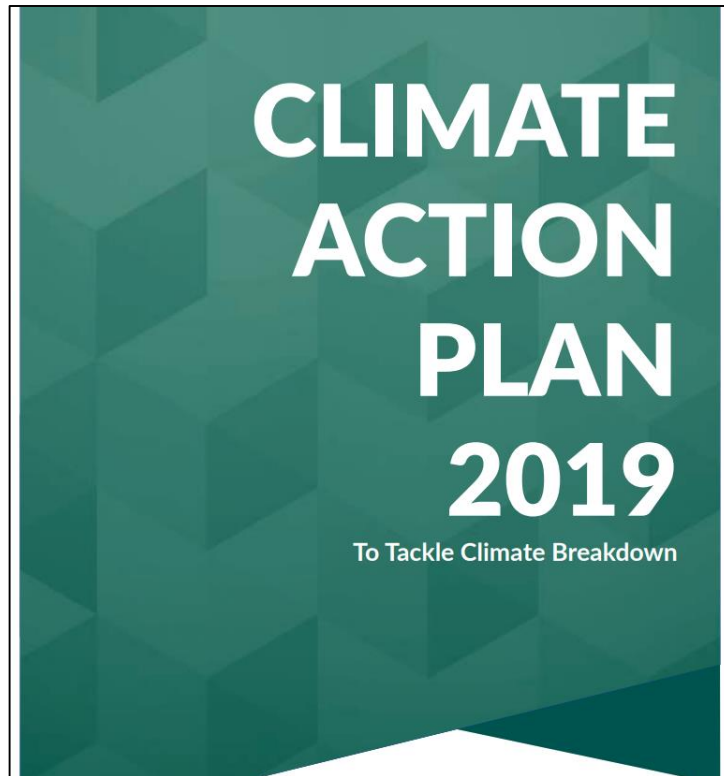
Source: DCCAE (2019)



High Level strategy



Focus on Consumers in Government Climate Policy



Consumers in the CAP:

- Adoption of new technologies across all sectors
 - >800,000 EVs by 2030
 - ~600,000 heat pumps by 2030
 - Retrofit 500,000 buildings to B2
 - Solar PV
- Changing energy use
 - Time of use tariffs + smart meters to facilitate VRE
 - Transport modal shift
- Financial measures
 - Carbon taxes
 - Environmental tax reform
 - Financial services
- Engaging citizens
 - Sustainable energy communities
 - Education and awareness



Conclusions

- Climate change is increasingly urgent concern
- Economics provides useful framework to consider policies, emissions levels
- Behaviour is difficult to quantify
- Policy decisions need to include consideration of societal welfare, ie social cost benefit analysis that includes externalities
- Students can use economics to understand political economy, market failures, policy instruments, fairness associated with climate change.



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