# The Second Generation Model:

## A Tool for Analyzing Greenhouse Gas Emissions and Mitigation Options


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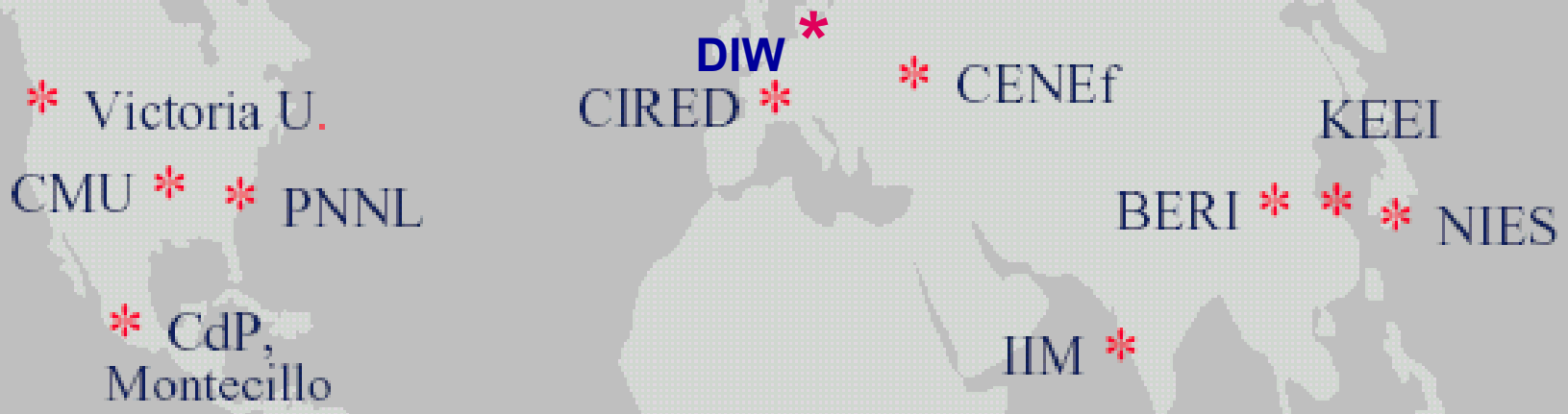
# SGM Collaborations

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- **US Department Of Energy, Office of Science**
- **US Environmental Protection Agency, Office of Atmospheric Programs**

# Overview:

- Second Generation Model (SGM) Goal/Objectives
- SGM Model History
- SGM Overview Description
  - Data Requirements
- Two Recent Examples Of SGM Application:
  - Carbon Policy in Germany (With DIW)
  - Non-$CO_2$ Emissions in the US (First Results)

# SGM Development Goals:

- Achieve Objectives of all Top-Down Economic Models
  - Project baseline greenhouse gas emissions over time for a country or group of countries
  - Explore the least-cost approaches to meet any particular emissions constraint
  - Provide a measure of the carbon price, in dollars per metric ton of carbon
  - Provide some measure of the overall cost of meeting an emissions target

- Customize SGM Regional Modules via Collaboration
  - SGM-US, -China, -India, -Japan, -FSU, -Mexico . . . -et al
  - SGM-Western Europe →SGM-Germany now disaggregated
  - SGM-Brazil →enhanced to include bio-fuels

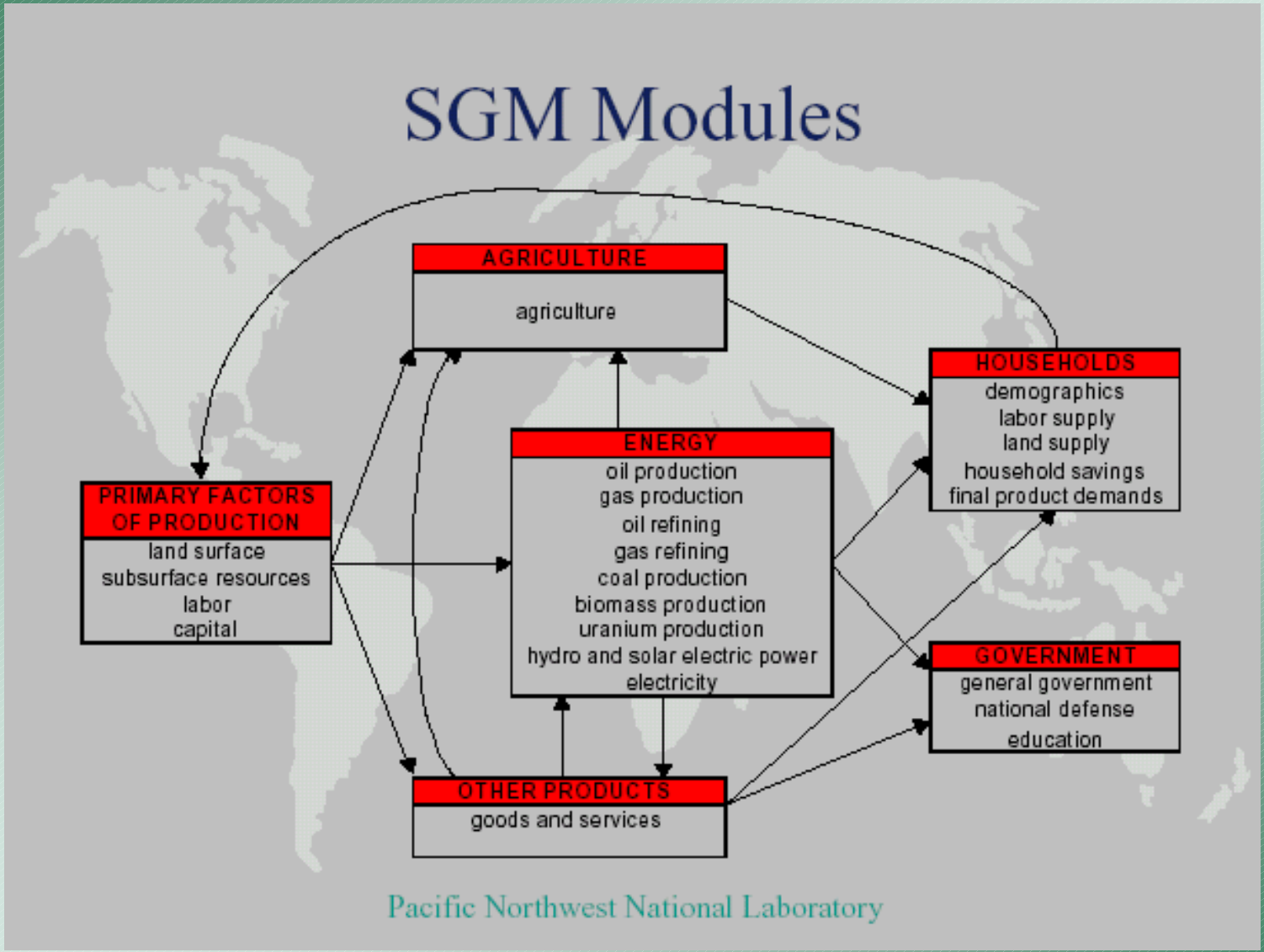
# Brief History of SGM:

- 1991 Began Development
  - Computable general equilibrium (CGE)
  - 7 Energy Sectors, Agriculture, Other
- 1993 SGM-US, 9 Production Sectors
  - Explored Cost of reducing carbon emissions in the US
- 1993-1999 Joint Development With International Partners
    - Incorporate unique features of each economy in a common framework
- 1999 13 Global Regions, 10 Production Sectors
  - **Studies of Individual Countries**
  - **Support CEA Interagency Analytical Team**
    - Annex I emissions mitigation
    - Carbon permit trading between countries
  - **Energy Modeling Forum Projects**
    - Stabilize carbon dioxide concentration
    - Meet Kyoto targets
- 2001 14 Global Regions, (+Brazil), 22 Production Sectors

# Second Generation Model

- General SGM features
  - Collection of compatible CGE models for 14 world regions
  - Five-year time steps from 1990 through 2050 (2100)
  - Industry specific capital stocks with a new vintage each time step
- 2002 incorporated non-CO2 greenhouse gases
  - Study emissions and mitigation strategies
  - Marginal abatement cost curves generated using constant-carbon-price experiments

# General SGM Structure



# SGM Regions

- Annex I
  - United States
  - Canada
  - Western Europe
    - Germany
  - Japan
  - Australia
  - Former Soviet Union
  - Eastern Europe
- Non Annex I
  - China
  - India
  - Brazil
  - Middle East
  - Mexico
  - South Korea
  - Rest of World

# Production Sectors in SGM

## e.g. SGM-Germany

1 agriculture
2 everything else (including services)
3 crude oil production
4 natural gas production
5 coal production
6 coke
7 electricity generation
8 oil refining
9 distributed gas
10 paper and pulp
11 chemicals
12 non-metallic minerals
13 primary metals
14 food processing
15 other industry and construction (including other mining)
16 rail and land transport
17 other transport

Model Sectors Tuned to Regional Economy **(21→17)**

Model Also Reflects Local Investment Criteria

# SGM Input-Output Table

**Condense Sectors According to Region/Problem**

| | production activities | C G I X M |
|---|---|---|
| intermediate inputs | interindustry flows | final demand |
| primary factors | value added | |

- **Expand Energy Sector**
- **Rows Are in Energy Units, Not Dollars**

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# SGM Derives Energy Inputs From IEA Energy Tables

energy inputs (fuels)

| | |
|---|---|
| production<br>imports<br>exports | sources |
| electricity generation<br>oil refining<br>coking | energy transformation |
| agriculture<br>industry<br>transport<br>residential buildings<br>commercial buildings | final consumption |

# Hybrid Input-Output Table Procedure

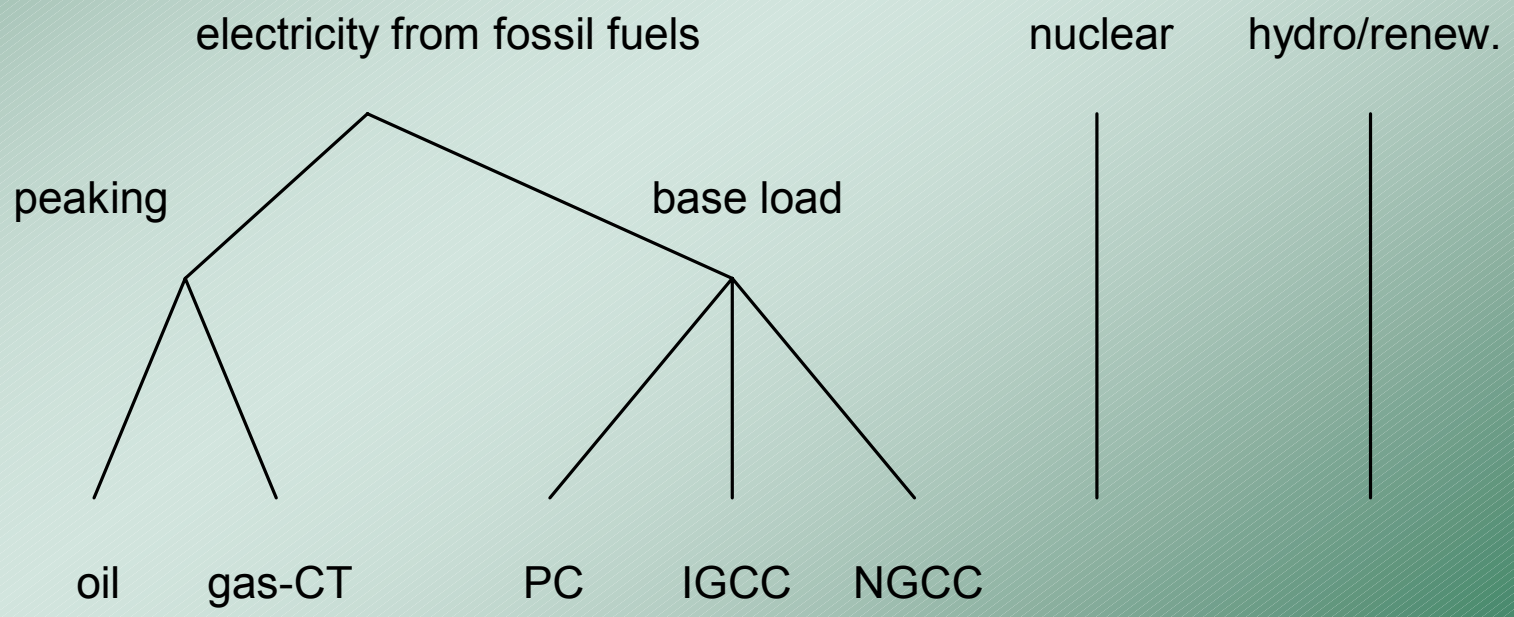
- Aggregate input-output table to SGM sectors for model base year (1995)
- Obtain energy balance table and convert units to joules
- Aggregate energy balance table to SGM format
- Transpose the energy balance table
- Combine into one table
  - Energy rows are from energy balance table
- Solve for a set of prices to balance the hybrid table
  - Relative prices of energy carriers depend on technical characteristics of energy transformation technologies
  - One price for each energy carrier
  - Energy taxes vary across consumers and production sectors

# SGM Data Requirements

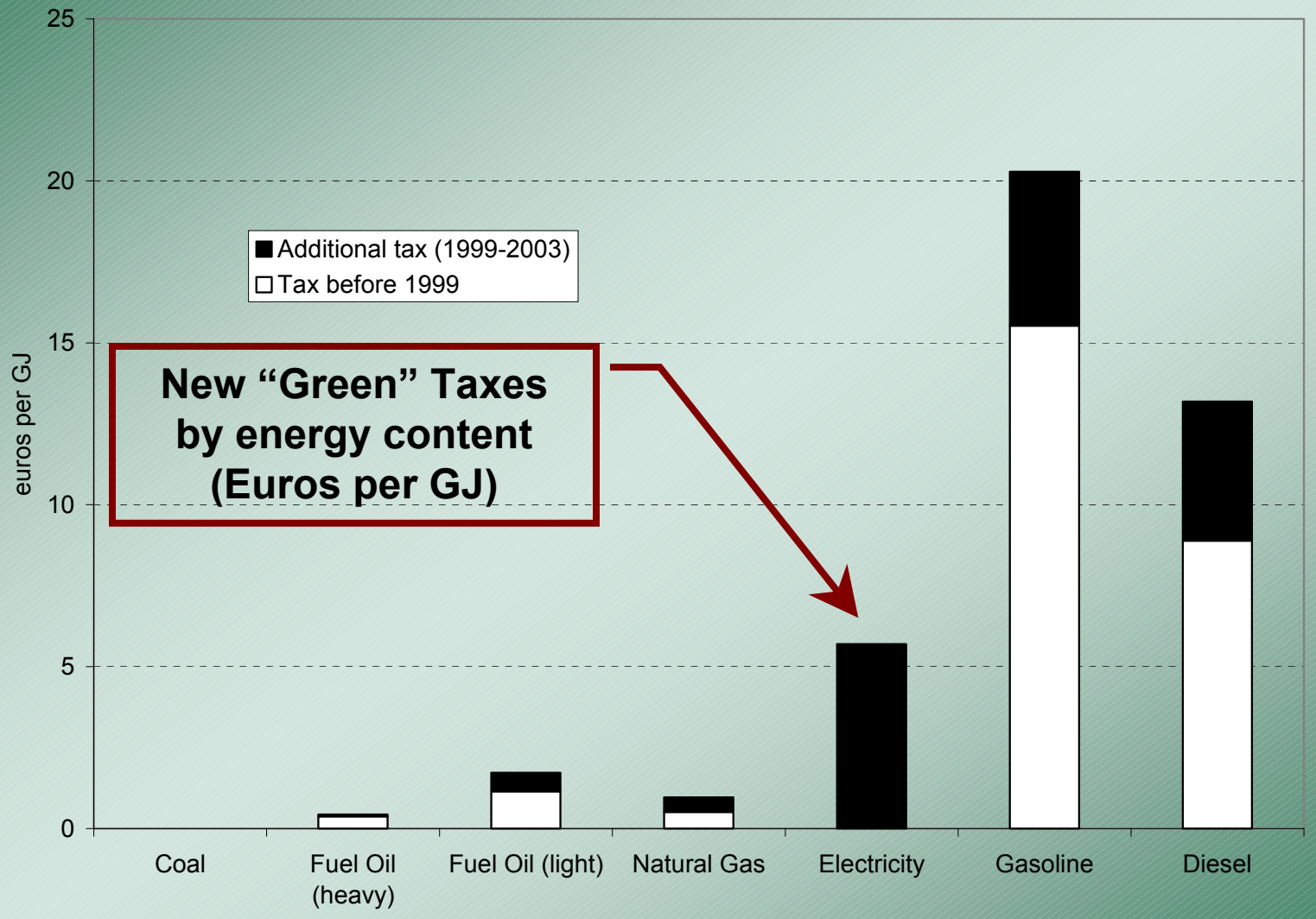
- **Economic Data**
  - input-output tables
  - national income accounts
- **Energy Consumption and Balances**
- **Technology Descriptions**
  - physical description of process
  - levelized cost of providing energy service

# Technology Representation:

- Most production sectors represented by single CES production function
- Some sectors (e.g. Electricity) use a nested logit (CCT) structure to allocate new investment to generating technologies
- Each electric generating technology represented by fixed-coefficient production function



# Example Of Recent Modeling:
## New "Green" Energy Taxes in Germany[1]

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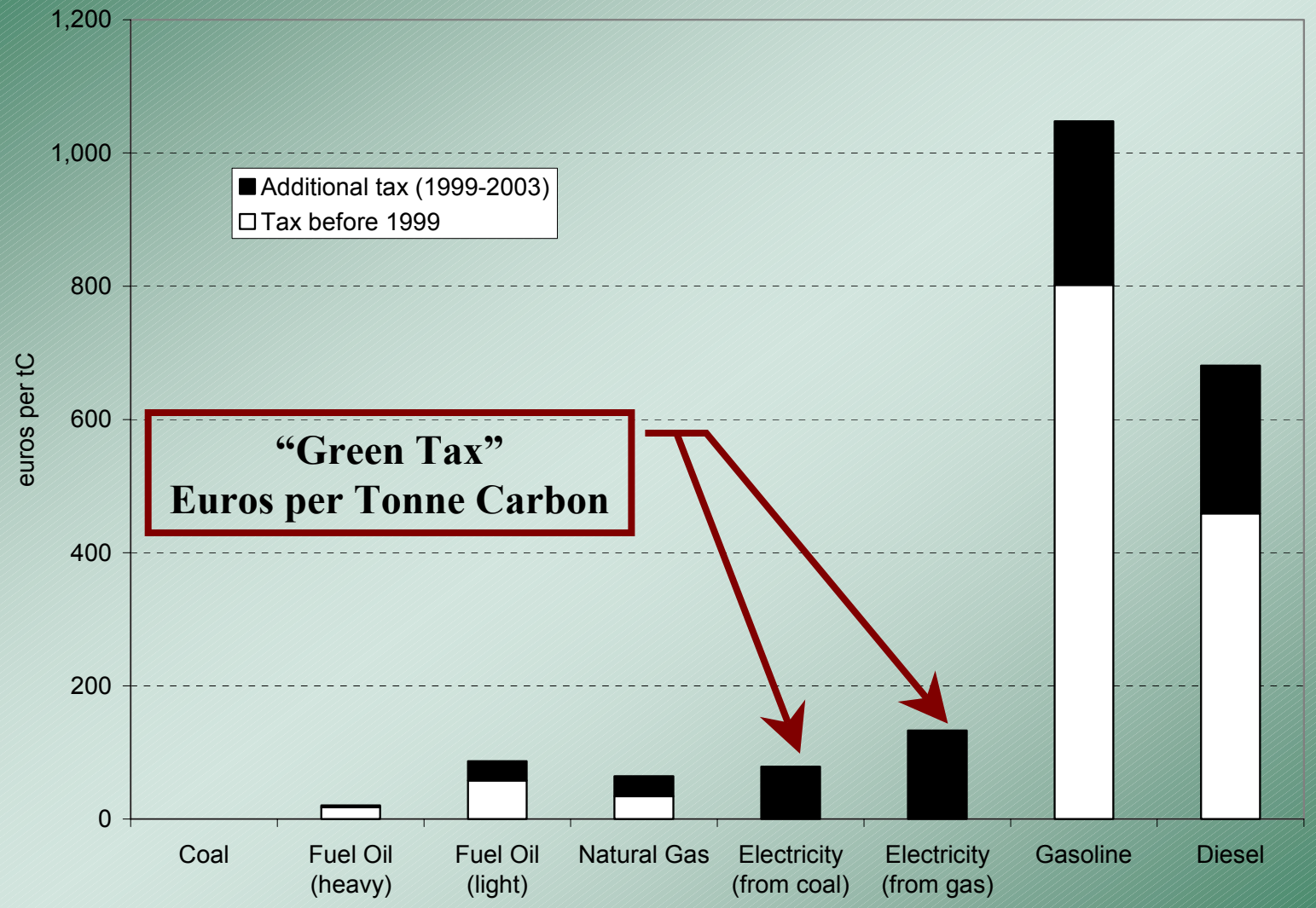
[1]In Collaboration with German Inst. For Economic Research

# Equivalent "Carbon" Taxes in Germany
## (Euros per ton of carbon)

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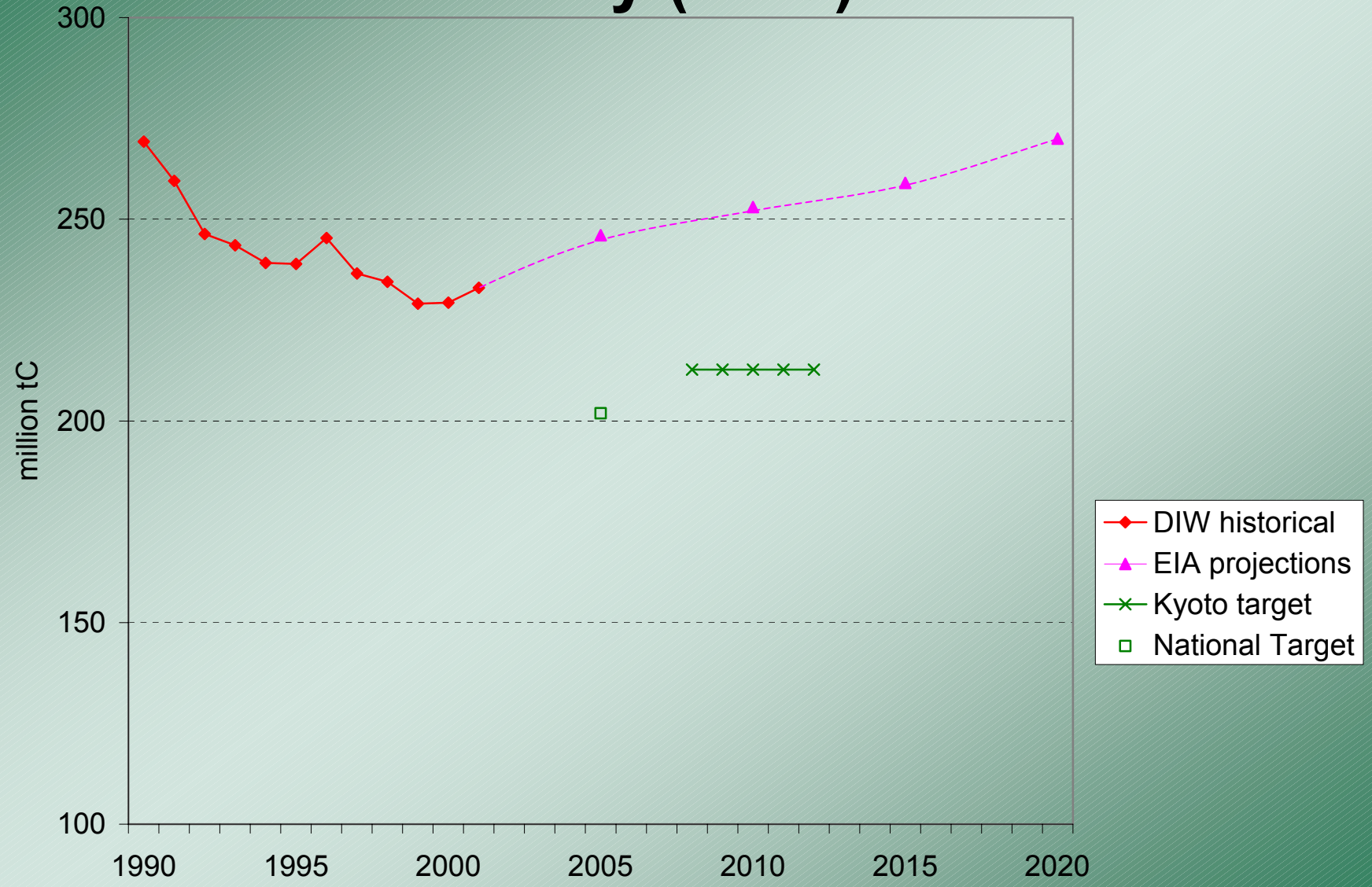
# DIW Historical & EIA Future Carbon Emissions in Germany (MTC)

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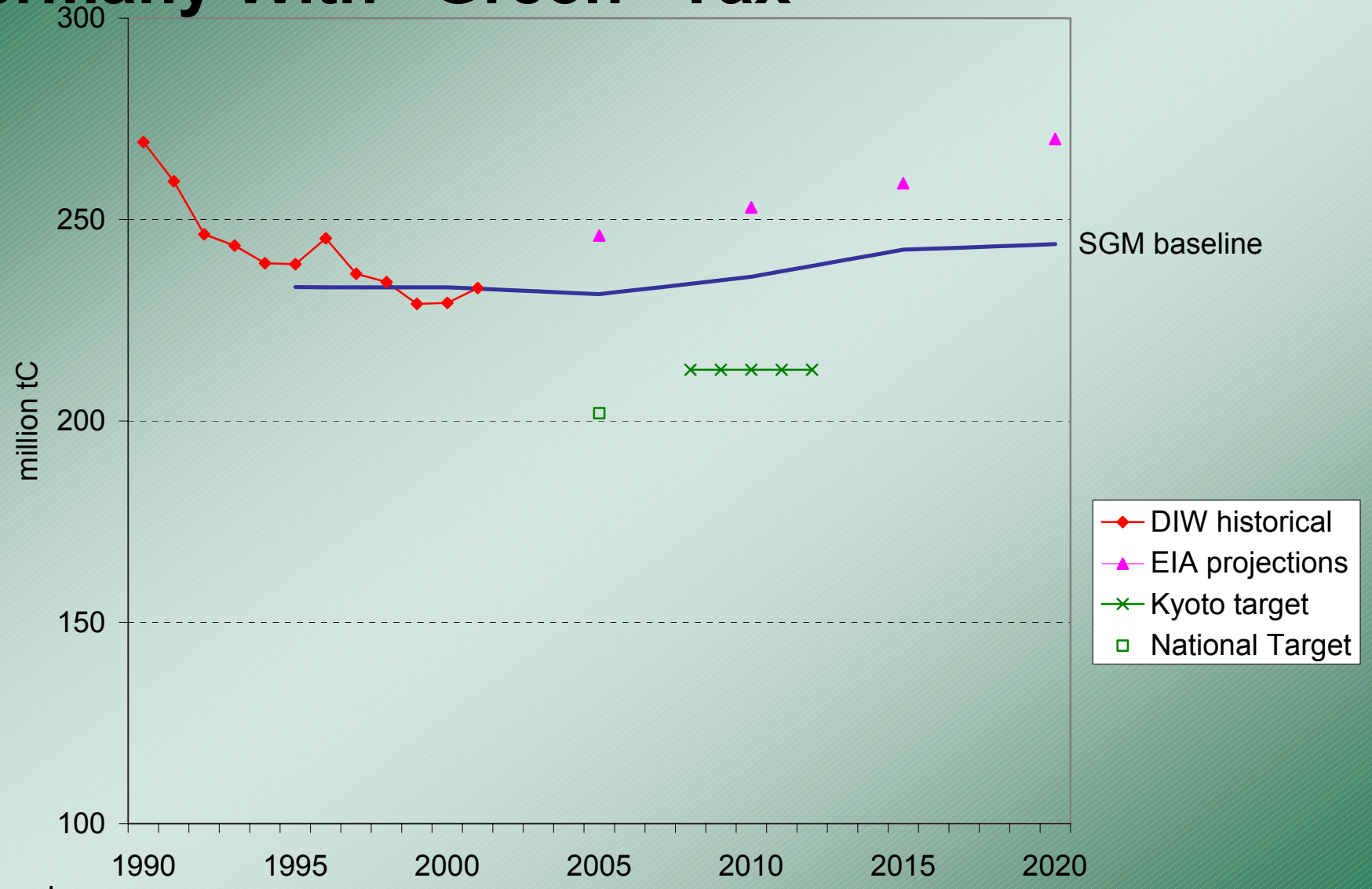
# SGM Projections of Carbon Emissions in Germany With "Green" Tax

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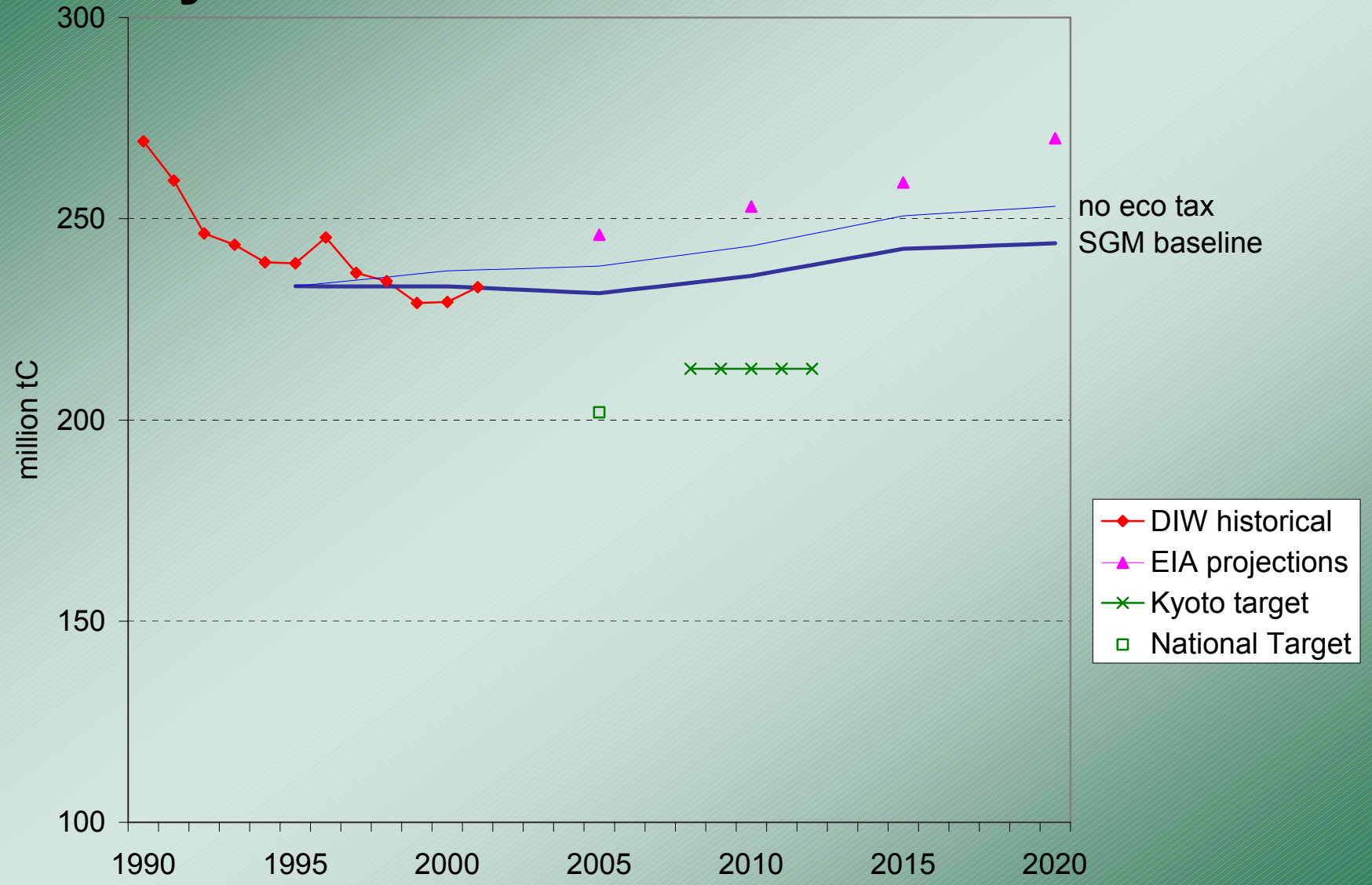
# Effect of "Green" Tax on Carbon Emissions in Germany

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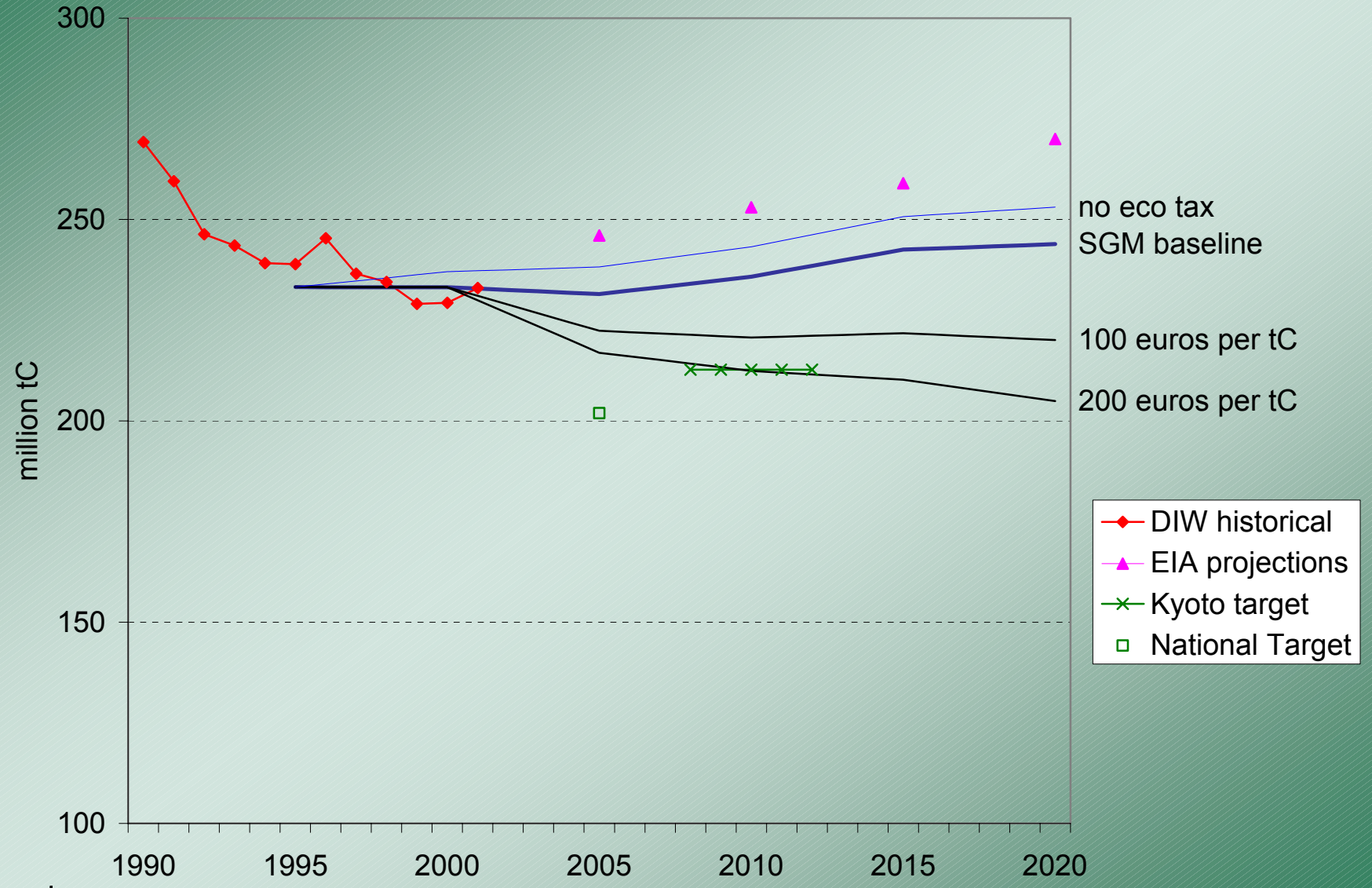
# Meeting Germany's Carbon Emission Targets

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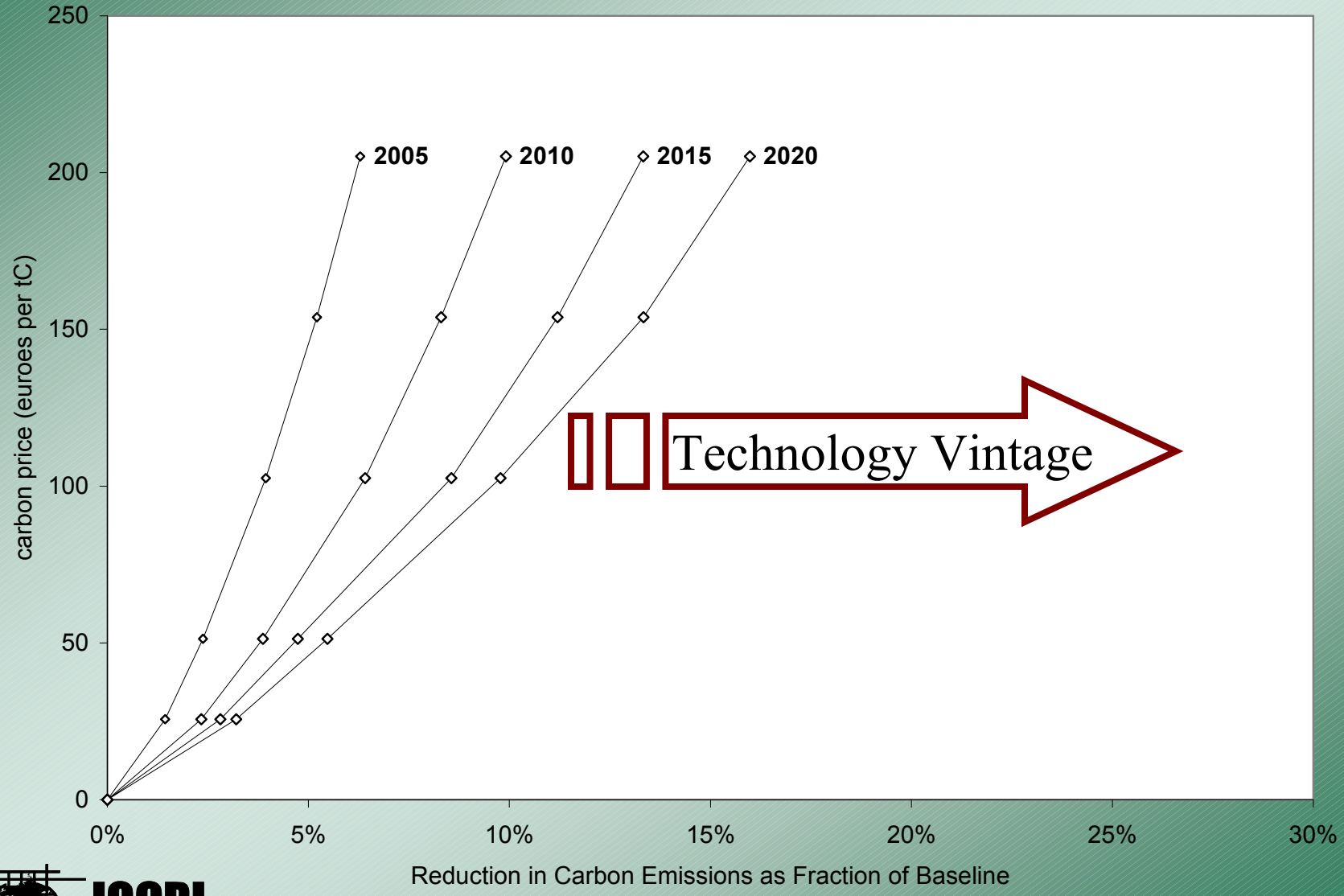
# Vintage Effect:
# SGM-Germany Marginal Abatement Curves

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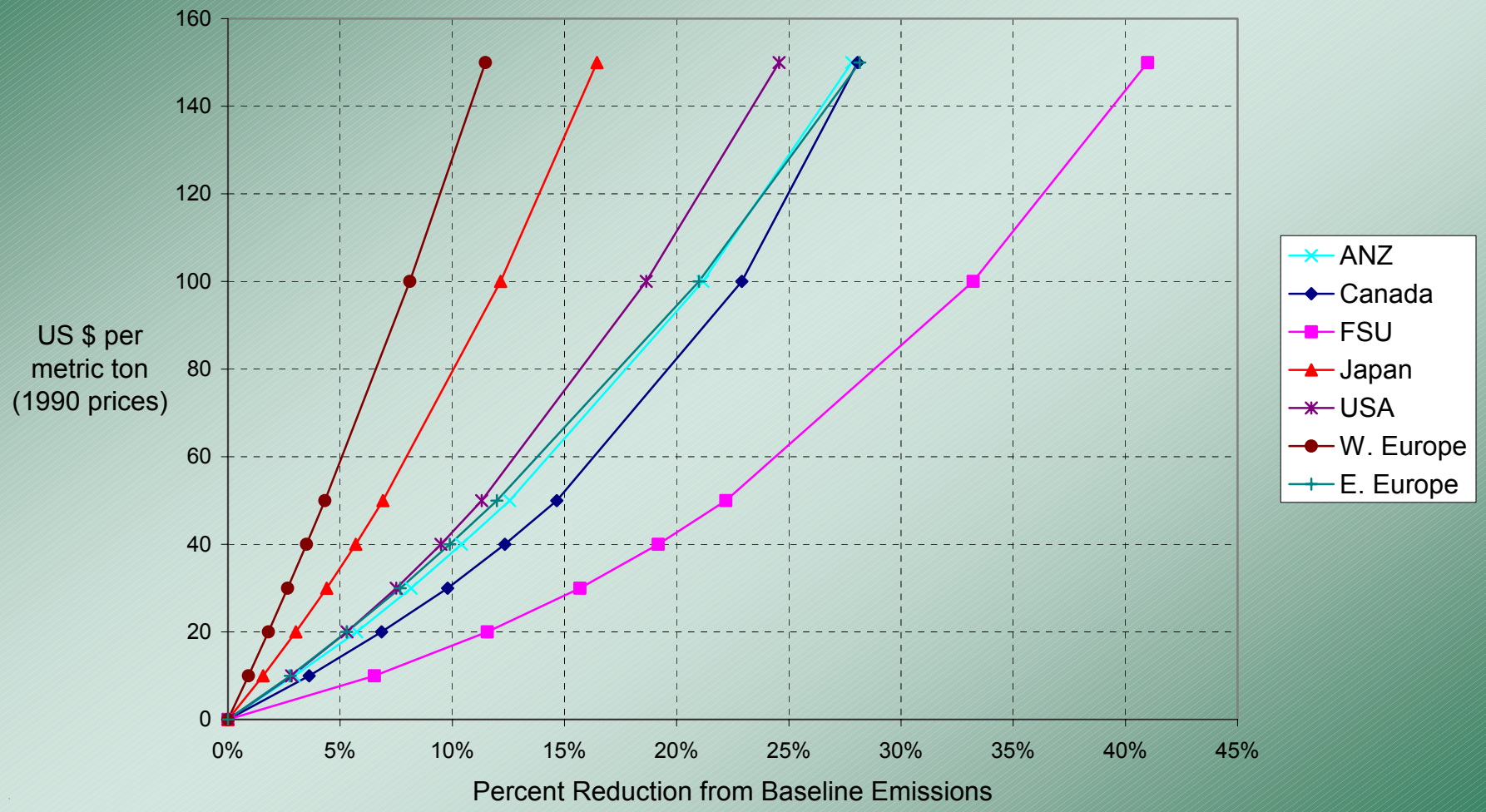
# Long-Run Marginal Abatement Curves
# Annex I Regions

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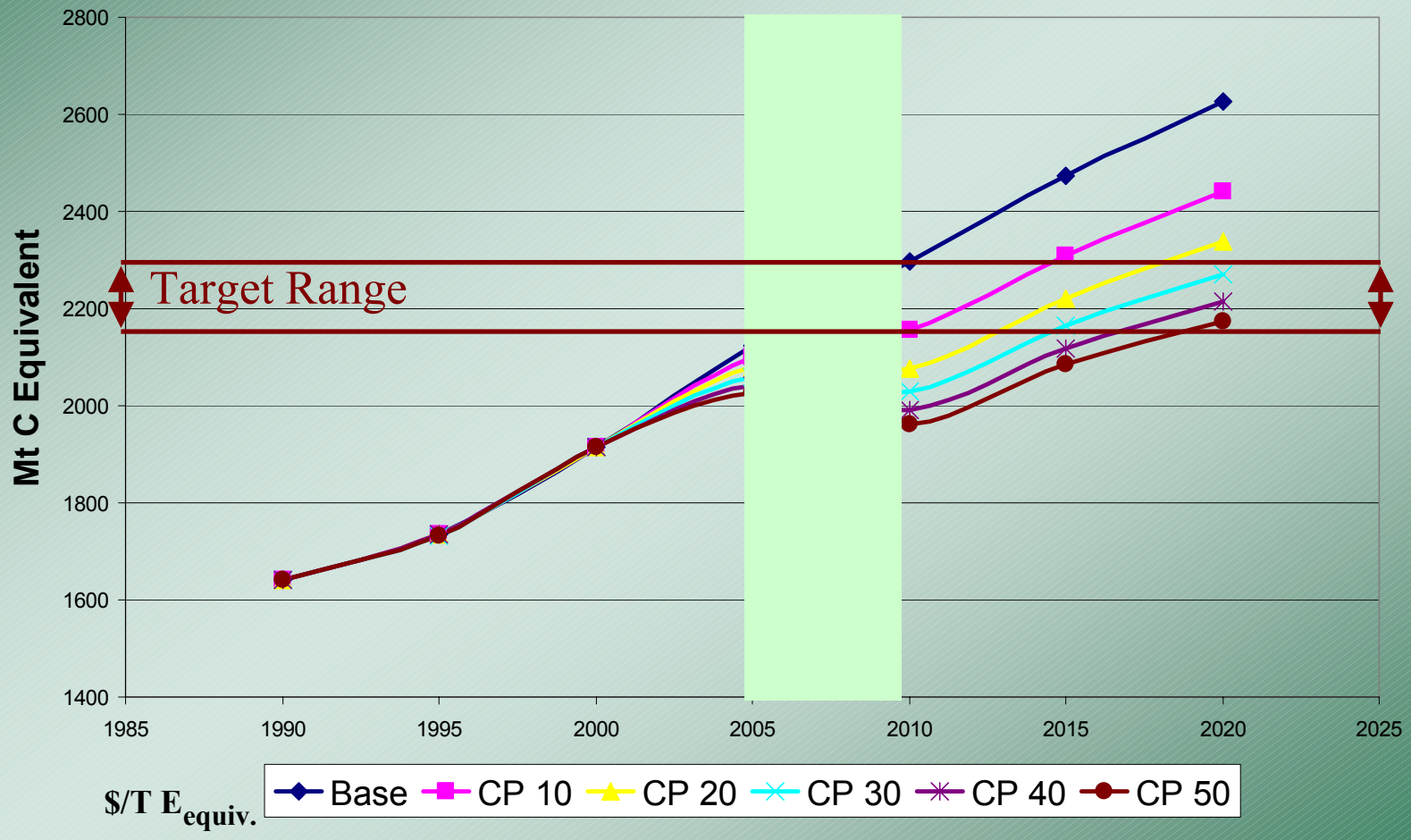
# Example Of Recent Analysis:

## Non $CO_2$ GHG Emissions in the US

- Include: Methane, Nitrous Oxide, High GWP gases in SGM-USA

- Explore: How controlling <u>all GHGs</u> would affect the Administration's current target ?

# Effect of Carbon Value Applied to All Greenhouse Gases in US

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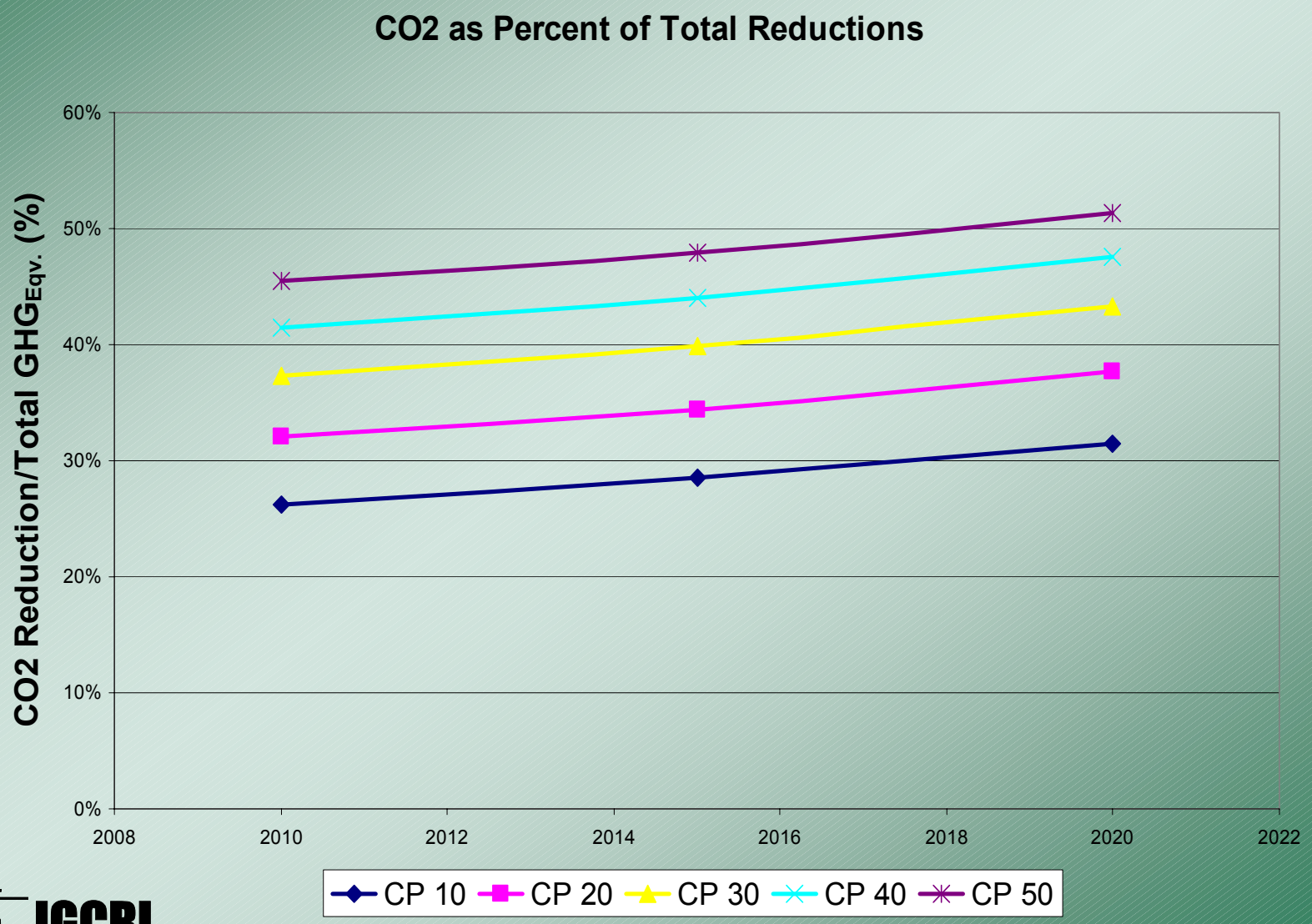
# Treating All GHG Together:

## Targets Non-$co_2$ GHG

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# Appendix

# SGM Data Requirements:

| Original Data | Derived Data |
|---|---|
| 1995 Input-Output Table<br>1995 Energy Balances | Hybrid Energy Input-Output Table |
| Annual Investment Data by Sector | Capital Stocks by Sector |
| Data on Fossil Fuel Resources | Resource Grades |
| Electricity Supply, generation, installed, capacity, energy consumption, capital costs, operating costs | Input-output representation of electricity generation by fuel |
| National Income Accounts | Tax rates, savings rates |