ENERGY TRANSITIONS: AN ECONOMISTS PERSPECTIVE

THE PUSH FOR RENEWABLE ENERGY

Washington Post

House Democrats unveil ambitious climate package, steering toward a net-zero economy by 2050

The Republicans on the House Select Committee on the Climate ... “Over 90 percent of all emissions will soon originate outside U.S. borders,” it said. ... the groundwork for a major climate bill during President Barack Obama's

2 weeks ago

New York Times

The Green New Deal Rises Again

The Green New Deal that Ocasio-Cortez has laid out aspires to power the U.S. economy with 100 percent renewable energy within 12 years and calls for “a job ...

Jan 8, 2019

Britain goes coal free as renewables edge out fossil fuels

By Justin Rowlatt
Chief environment correspondent

10 June 2020 | 1006

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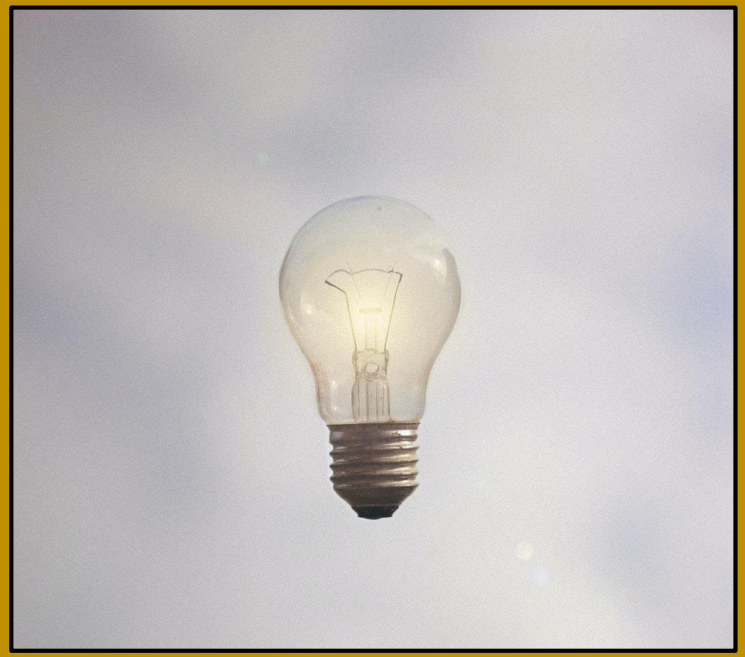
QUESTIONS WE'LL LOOK AT



This will **not** be a comprehensive review of energy transitions.

We will examine a few highlights of energy transitions from an economist's perspective.

In particular, we will ask a few questions:

1. What have energy transitions looked like in the past?
2. Why might an economist argue for a transition to renewable energy sources?
3. What does energy use look like today and what policies could facilitate a renewable energy transition?

LESSON OBJECTIVES

01

History of Energy Use and Energy Transitions

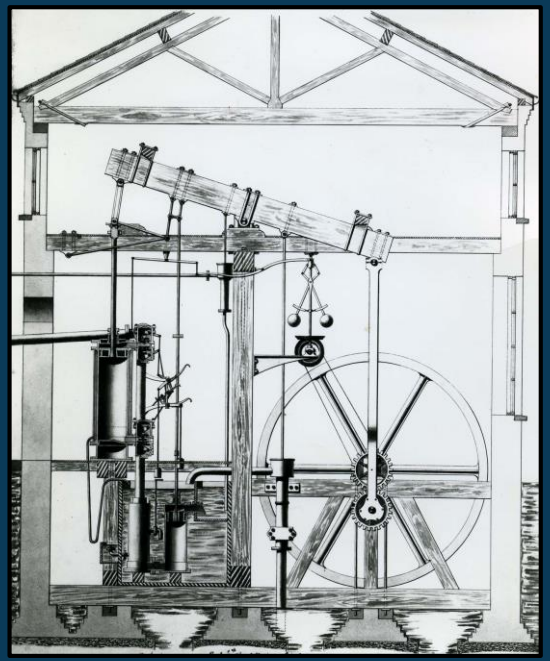
02

Analyze and Explain Current Push for Clean Energy Transition

03

Analyze Policies for Clean Energy Transition

ENERGY USE AND ENERGY TRANSITIONS



Before we can talk about an energy transition toward renewable energy, we first need to look at the past.

So here is a **brief** history of energy use and energy transitions and a **few** key insights.

- Smil (2016)
- https://www.sciencedirect.com/science/article/pii/S2214629616302006

01

HISTORY OF ENERGY USE AND ENERGY TRANSITIONS

HISTORY OF PRIMARY ENERGY CONSUMPTION

What is an *energy transition*?

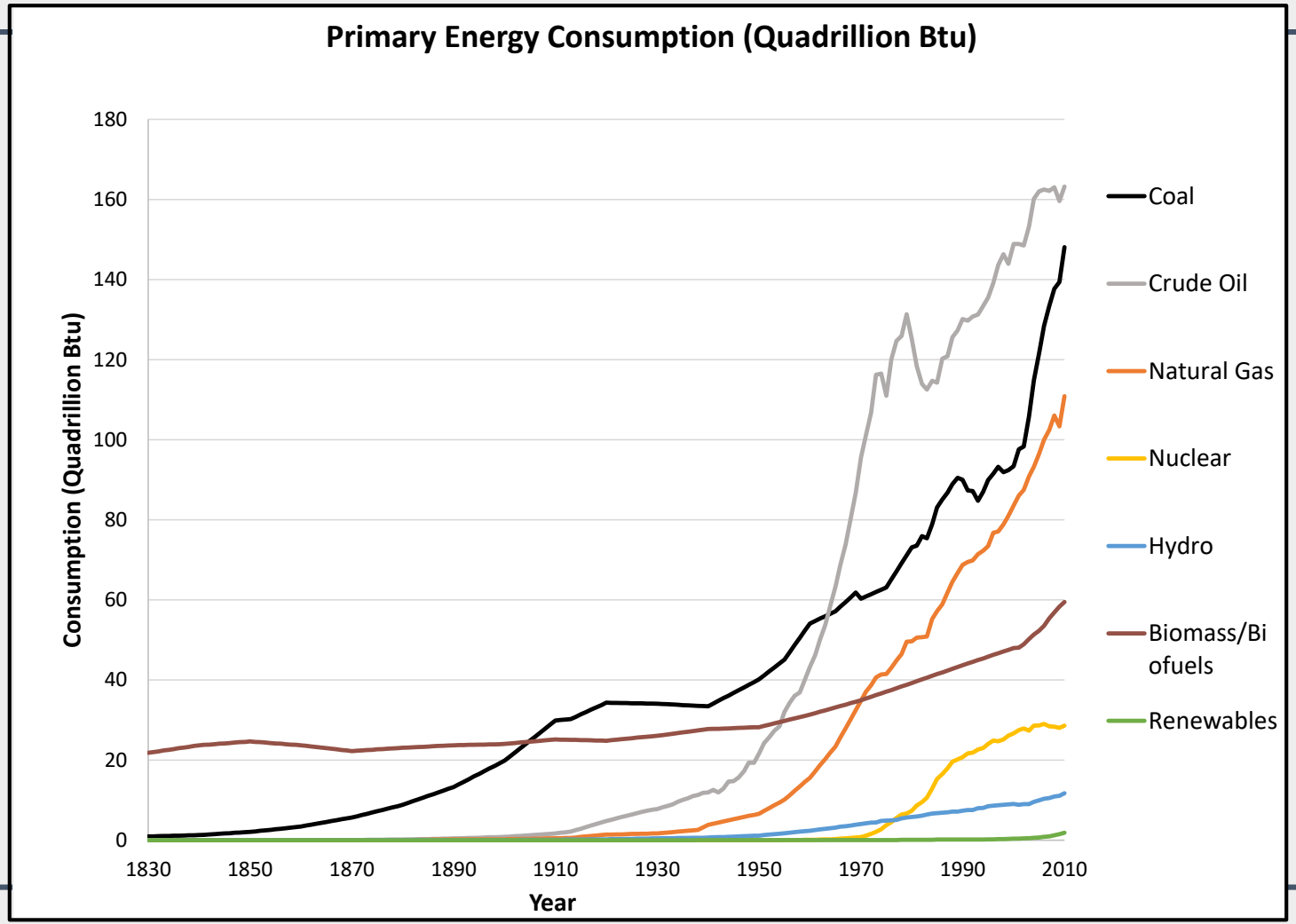
- A structural change in the energy system
- Typically involves changes to the demand or supply of energy source

We are going to focus on *primary energy sources*.

A *primary energy source* is any naturally occurring energy source.

- Eg. Biomass, natural gas, solar, etc.
- As opposed to *secondary energy* (eg. Electricity) which acts as a carrier and is a converted form of a primary energy source.

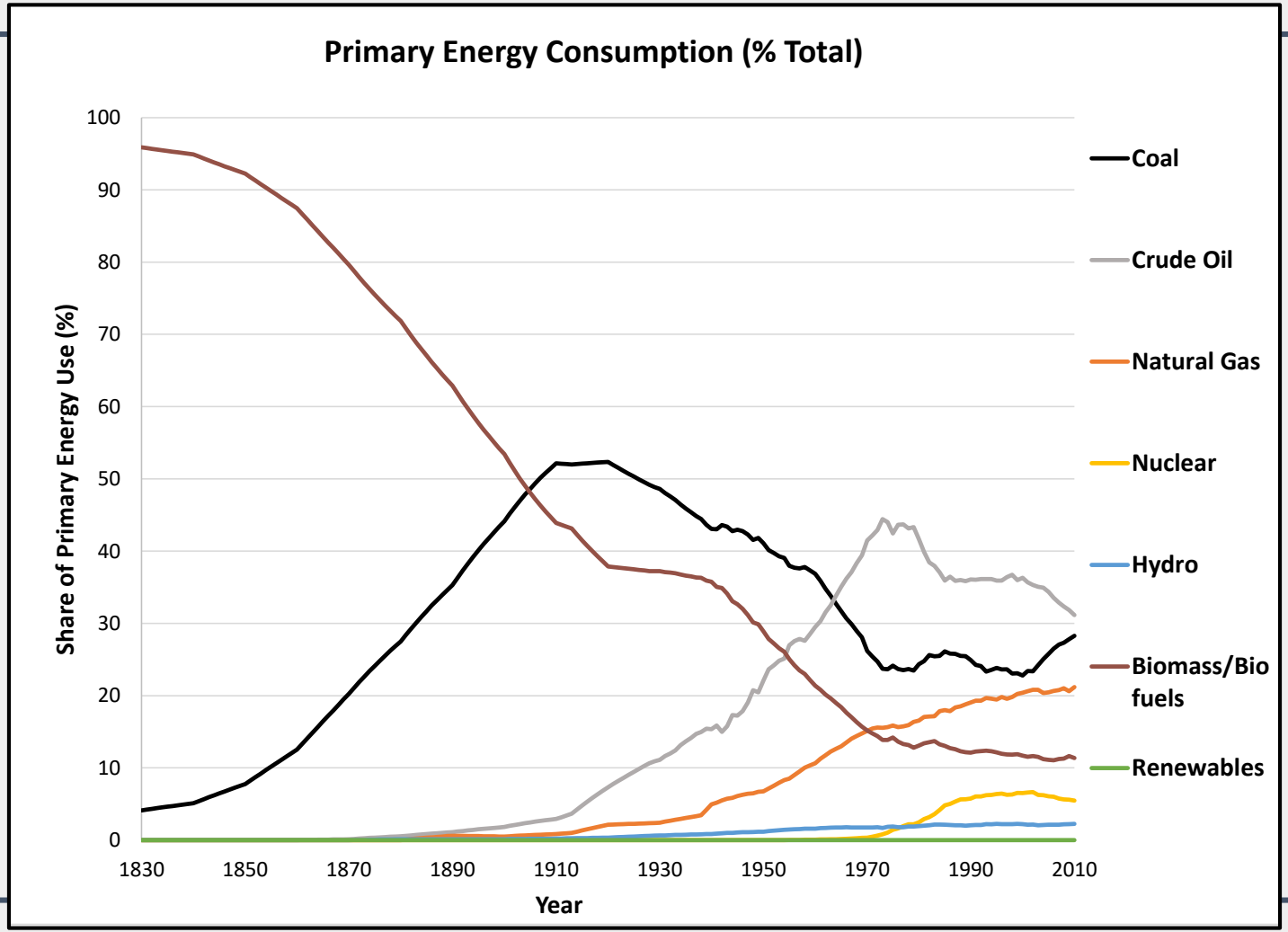
Consumption levels across different primary energy sources has changed significantly over the past two centuries.


Primary Energy Consumption (Quadrillion Btu)
Consumption (Quadrillion Btu)
180
160
140
120
100
80
60
40
20
0
1830
1850
1870
1890
1910
1930
1950
1970
1990
2010
Year
Coal
Crude Oil
Natural Gas
Nuclear
Hydro
Biomass/Biofuels
Renewables

INSIGHTS FROM THE PAST

Here are a few insights from the past:

1. Global energy transitions have been slow.


Primary Energy Consumption (% Total)
Share of Primary Energy Use (%)
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70
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1870
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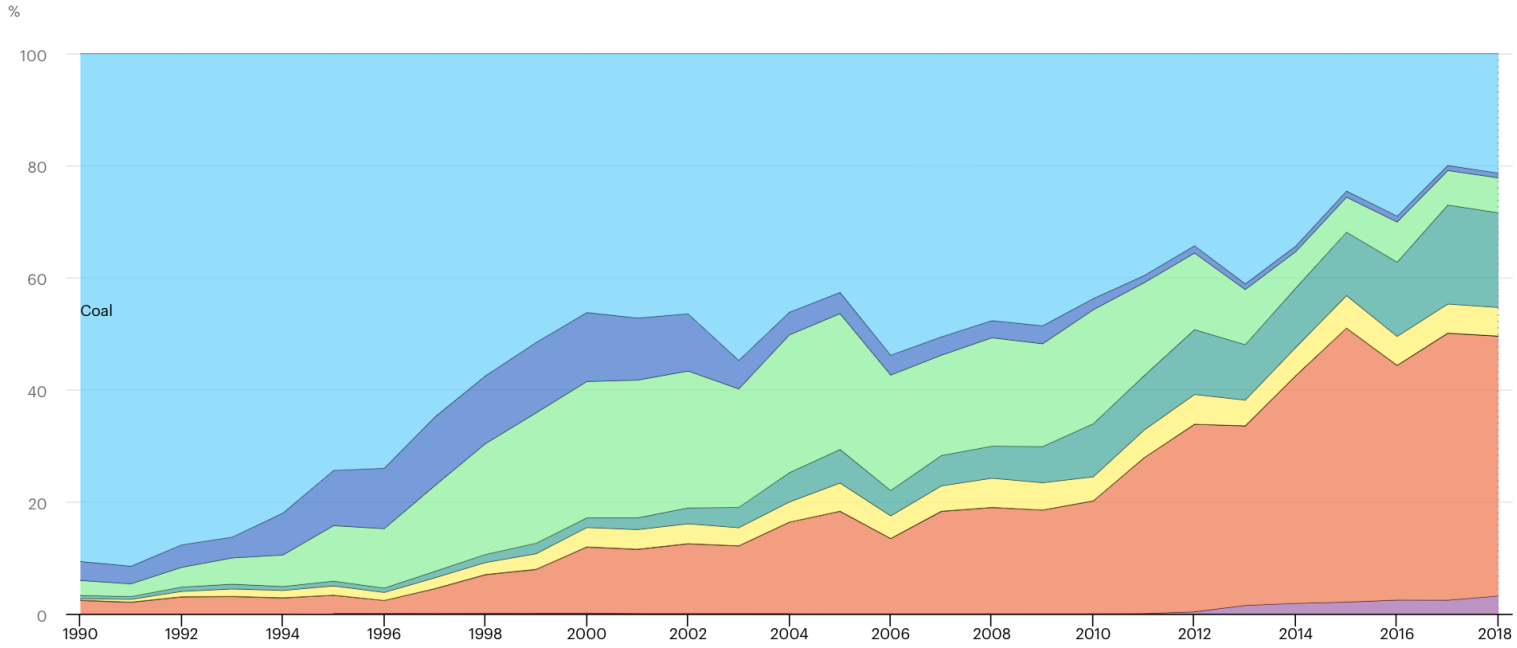
1950
1970
1990
2010
Year
Coal
Crude Oil
Natural Gas
Nuclear
Hydro
Biomass/Bio fuels
Renewables

INSIGHTS FROM THE PAST

Here are a few insights from the past:

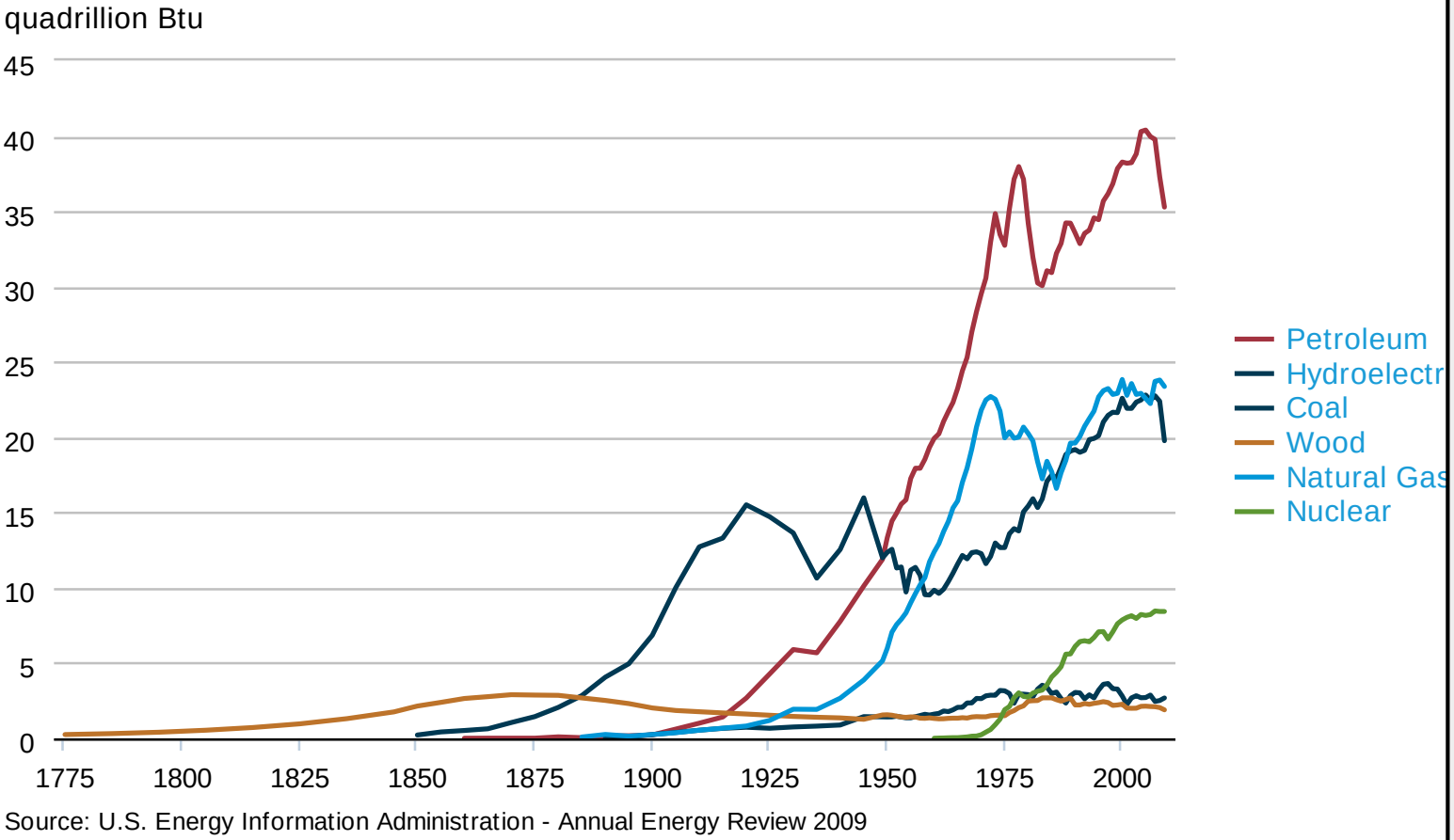
1. Global energy transitions have been slow.
2. The speed of national energy transitions is more varied.

Electricity generation by source, Denmark 1990-2018



Coal Oil Natural gas Biofuels Waste Hydro Wind Other sources Solar PV

History of energy consumption in the United States, 1775-2009

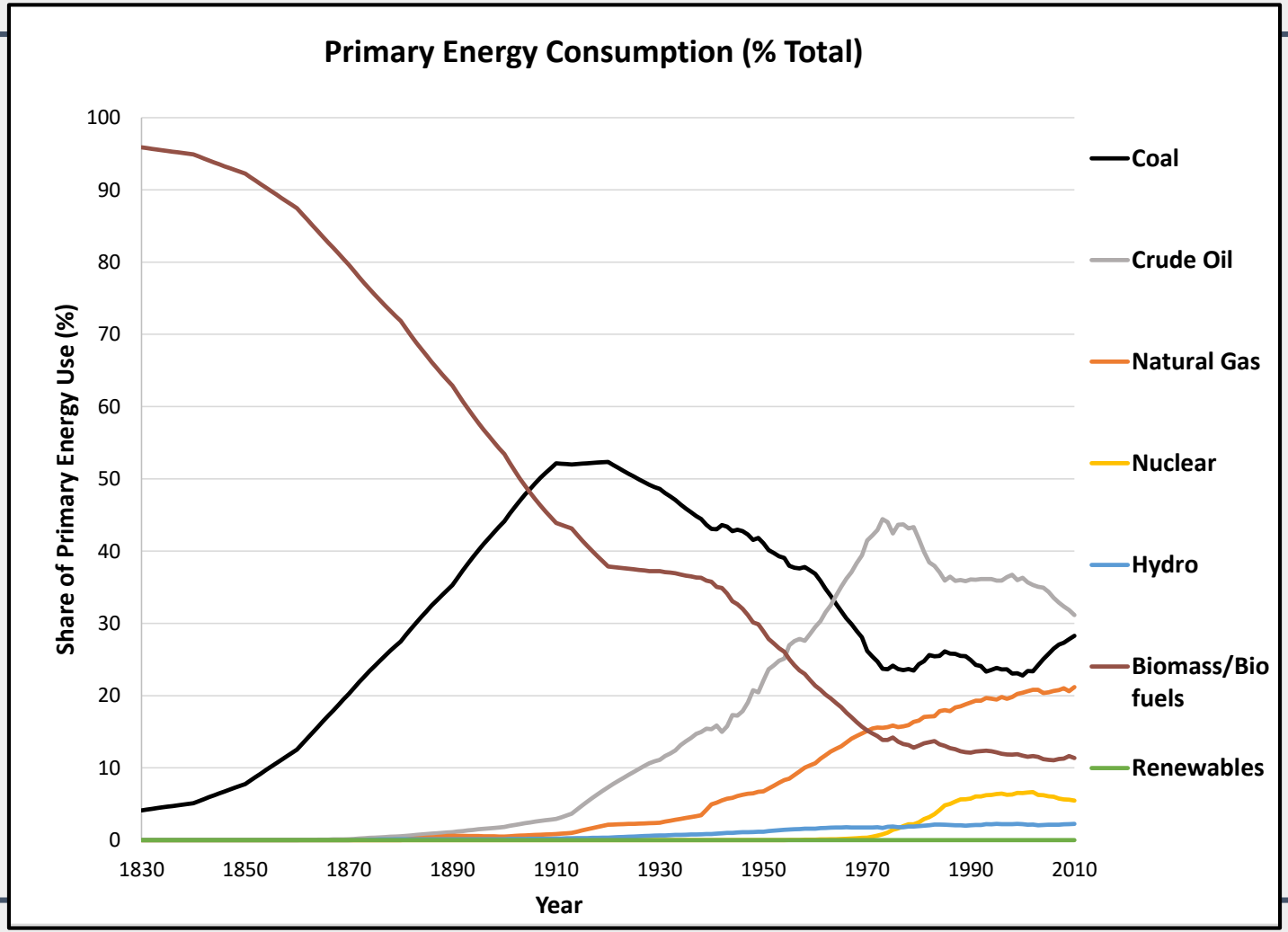


Source: U.S. Energy Information Administration - Annual Energy Review 2009

INSIGHTS FROM THE PAST

Here are a few insights from the past:

1. Global energy transitions have been slow.
2. The speed of national energy transitions is more varied.
3. Today's energy consumption is still highly dependent on fossil fuels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Share of Primary Energy Use (%)
100
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1930
1950
1970
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2010
Year
Coal
Crude Oil
Natural Gas
Nuclear
Hydro
Biomass/Bio fuels
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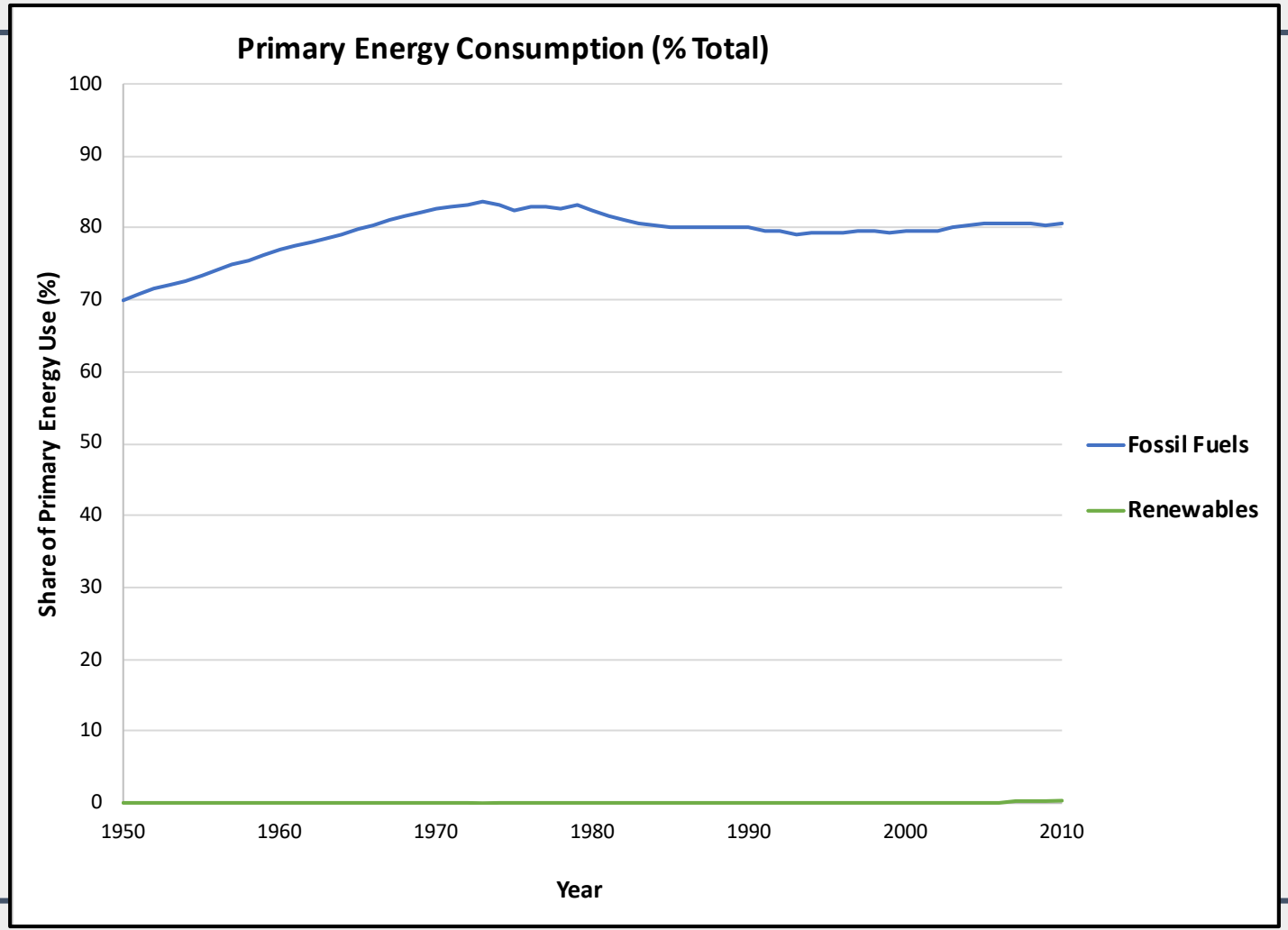
INSIGHTS FROM THE PAST

Here are a few insights from the past:

1. Global energy transitions have been slow.
2. The speed of national energy transitions is more varied.
3. Today's energy consumption is still highly dependent on fossil fuels
4. Little evidence that push for renewables is accelerating or changing carbon intensities


Primary Energy Consumption (% Total)
Share of Primary Energy Use (%)
100
90
80
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0
1950
1960
1970
1980
1990
2000
2010
Year
Fossil Fuels
Renewables

INSIGHTS FROM THE PAST

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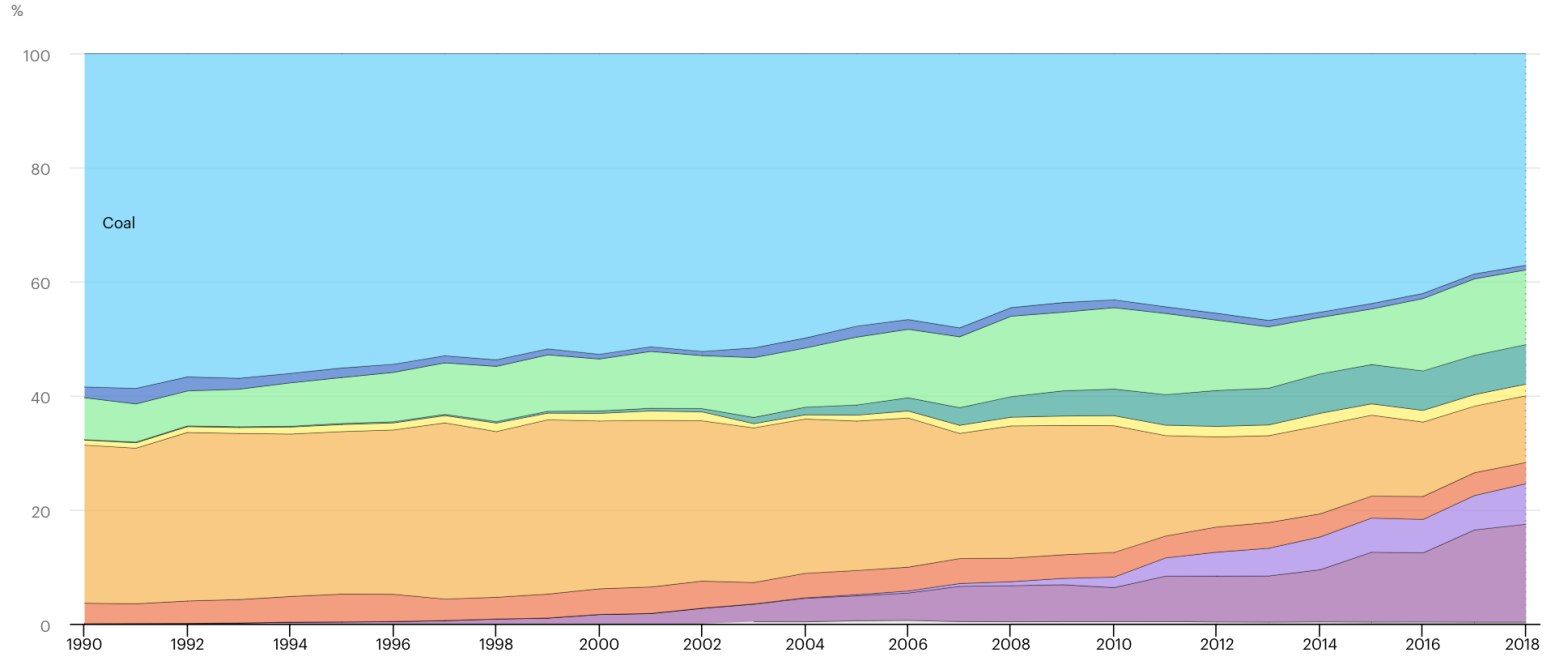
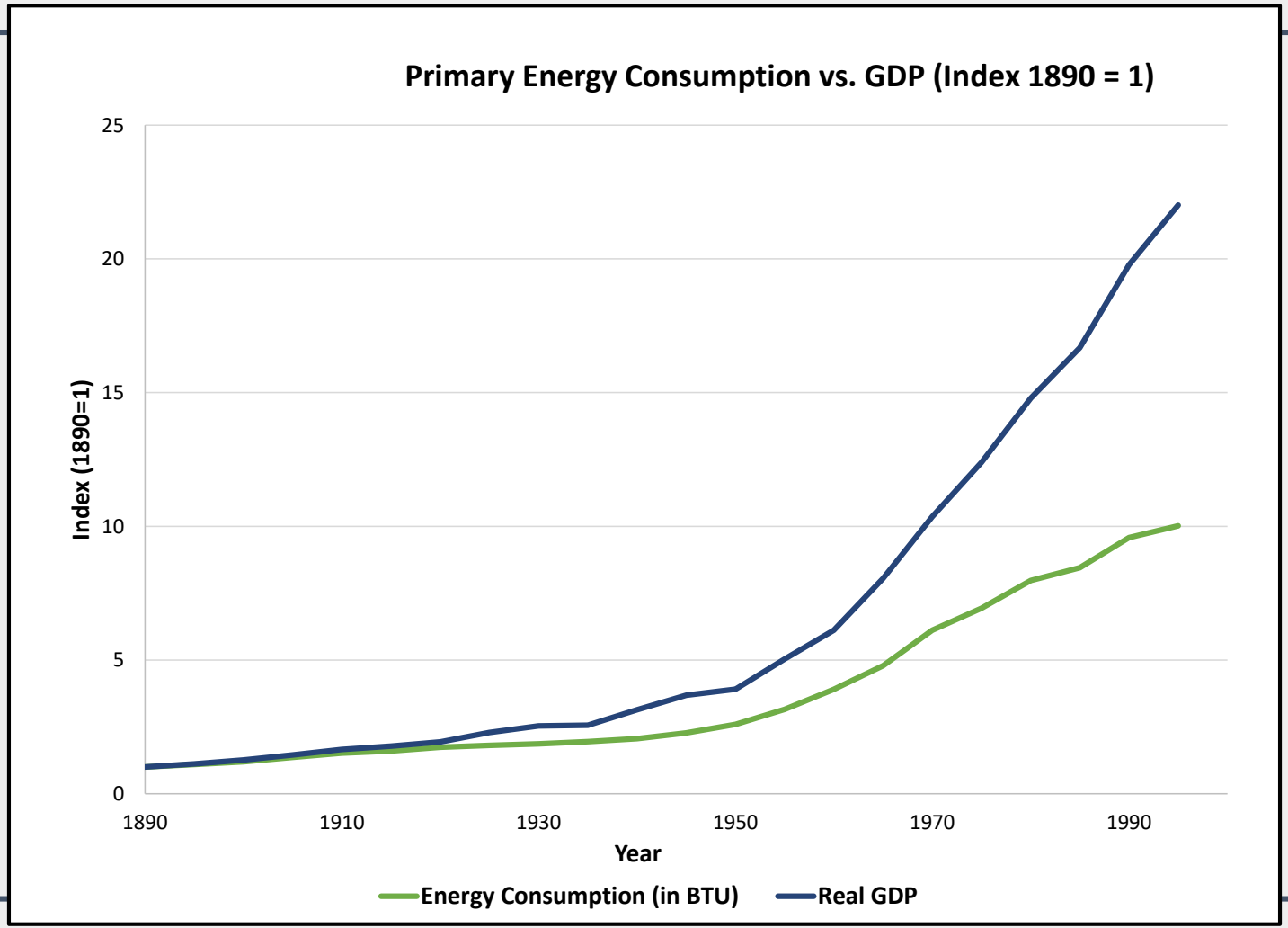
1. Global energy transitions have been slow.
2. The speed of national energy transitions is more varied.
3. Today's energy consumption is still highly dependent on fossil fuels
4. Little evidence that push for renewables is accelerating or changing carbon intensities
5. Renewables transition has been slow even in countries with determined efforts

Electricity generation by source, Germany 1990-2018



Coal Oil Natural gas Biofuels Waste Nuclear Hydro Solar PV Wind Other sources Geothermal Solar thermal


Primary Energy Consumption vs. GDP (Index 1890 = 1)
Index (1890=1)
25
20
15
10
5
0
1890
1910
1930
1950
1970
1990
Year
Energy Consumption (in BTU)
Real GDP

WHY IS THERE A PUSH FOR A CLEAN ENERGY TRANSITION?

ECONOMIC ARGUMENTS FOR CLEAN ENERGY TRANSITION

Our goal is economic efficiency

As we've seen, the basis for government intervention would be market failure.

So where might there be a case for market failure around energy production/consumption?

Where are there externalities?

FOSSIL FUELS ARE DEPLETABLE

Fossil fuels, the top 3 primary energy sources, are natural resources.

- Petroleum
- Natural Gas
- Coal

Specifically, these are **depletable** resources.

A key source of market failure for depletable resources was the opportunity cost of depleting a resource

- Scarcity cost

FOSSIL FUELS RELEASE GREENHOUSE GASES (GHG)

Fossil fuels, the top 3 primary energy sources, are natural resources.

- Petroleum
- Natural Gas
- Coal

Burning these resources to produce energy releases GHGs as a byproduct.

GHGs are the driver of climate change, which has associated economic damages

- Public good problem

DEVELOPMENT OF INNOVATIVE TECHNOLOGIES

Research and development (R&D) for innovative technologies is costly

- E.g. Development of more efficient solar panels

However, innovators only receive a fraction of the benefits

- Others benefit from new technology

Thus, innovators will underinvest in R&D.

EXTERNALITIES

Fossil fuels are depletable resources

- Negative externality

Burning fossil fuels generates GHGs, driving climate change

- Negative externality

Development of innovative technologies

- Positive externality

WHAT ARE SOME OTHER COMMON ARGUMENTS FOR CLEAN ENERGY TRANSITION?

COMMON ARGUMENTS

Enhanced energy independence
- National benefit

Job creation
- Local/regional benefit

Lower energy prices
- Local/regional/national benefit

WHAT DOES SECURITY / INDEPENDENCE MEAN?

What is the goal?

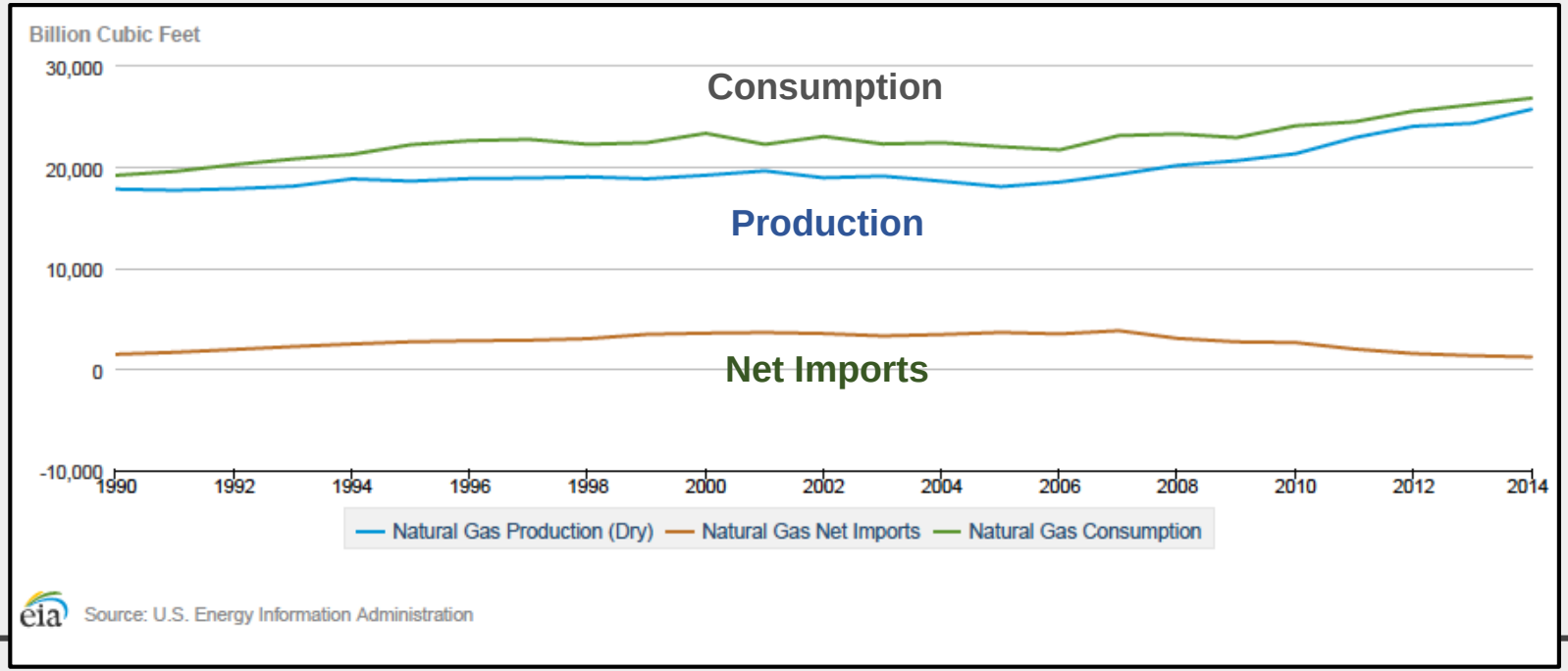
- Insulate from certain trading partners
- Protect from price shocks

Let's consider each fossil fuel source

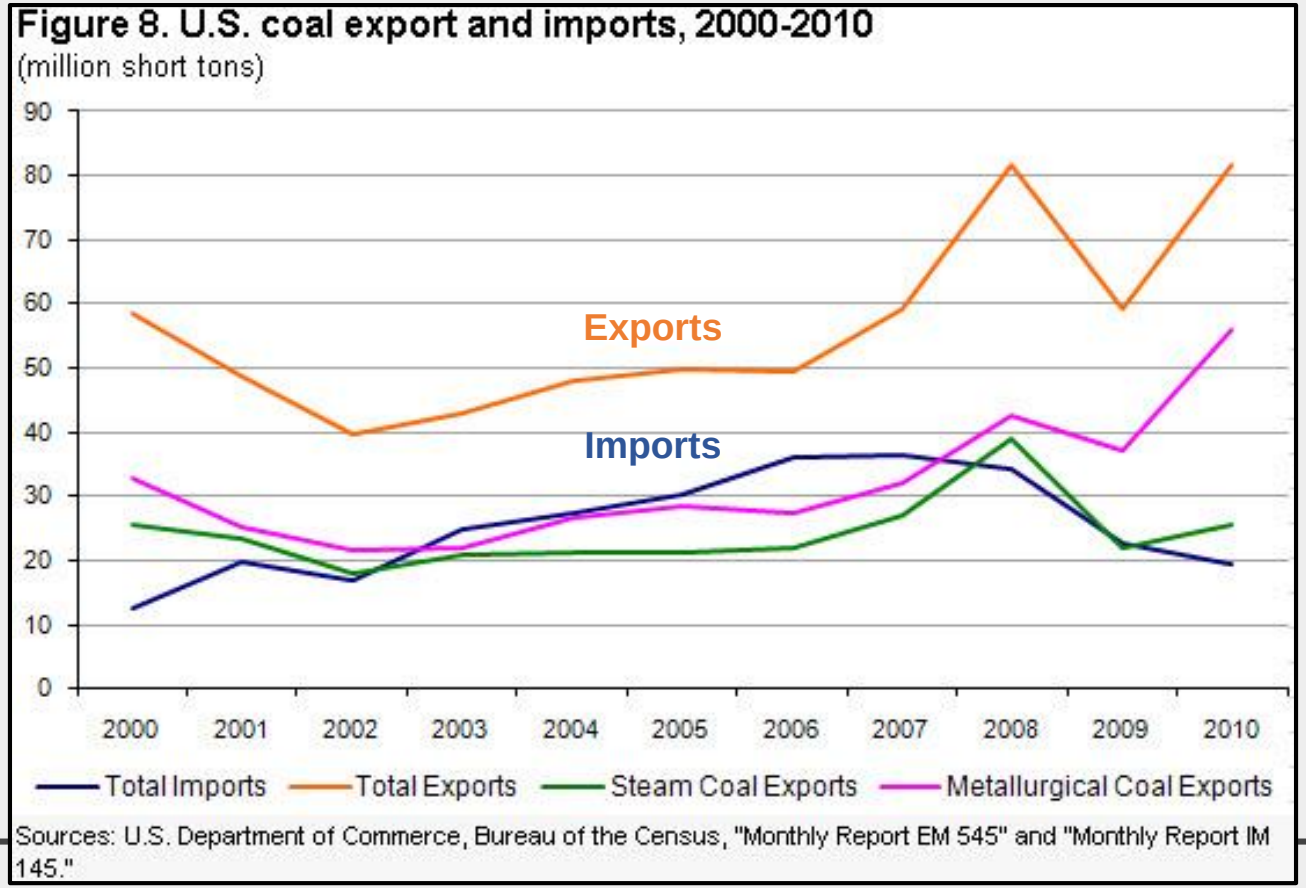
- Natural Gas
- Petroleum
- Coal

We'll take the US perspective

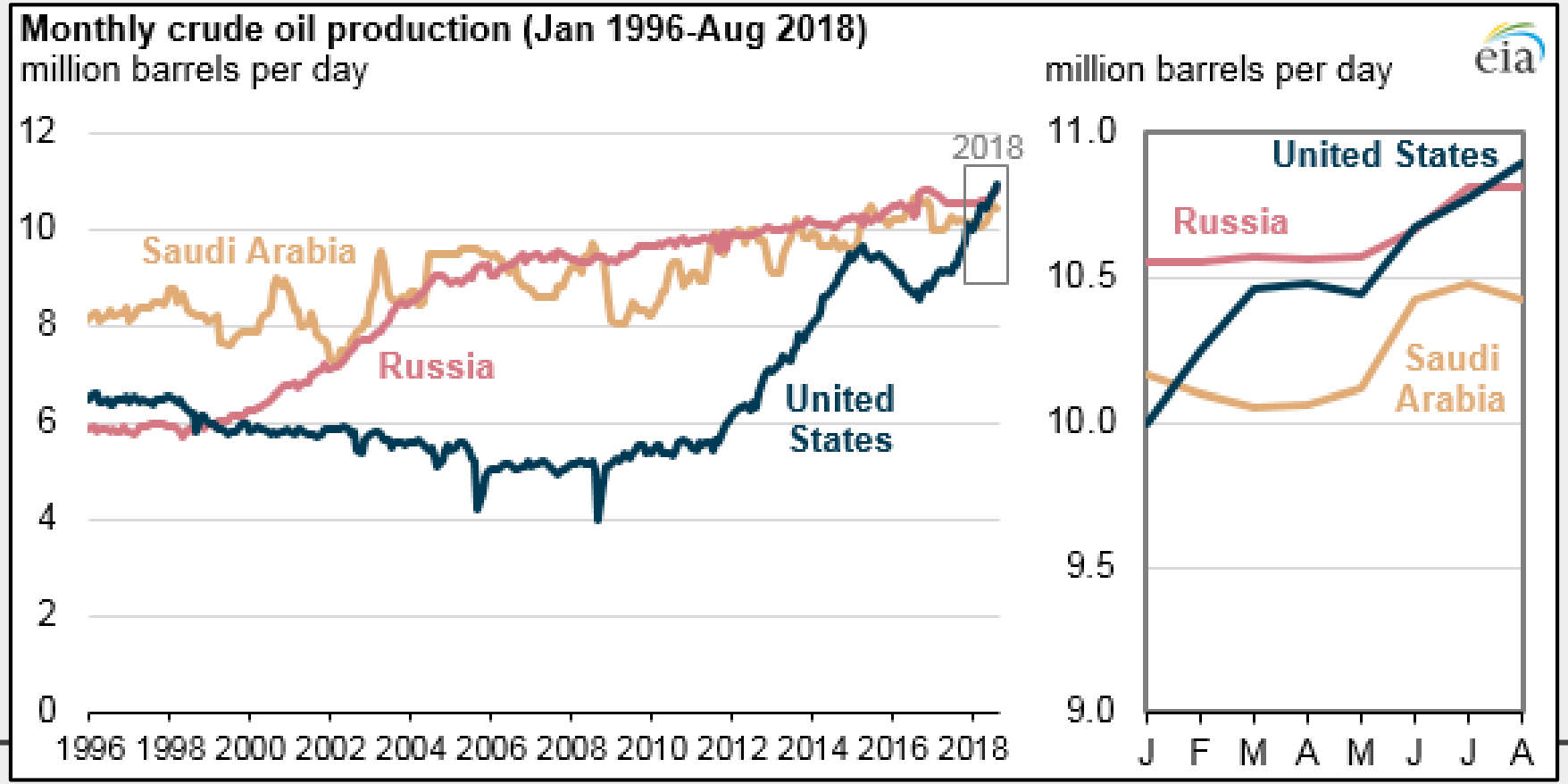
NATURAL GAS INDEPENDENCE



COAL INDEPENDENCE



PETROLEUM INDEPENDENCE



WHAT DOES SECURITY / INDEPENDENCE MEAN?

What is the goal?

- Insulate from certain trading partners
- Protect from price shocks

Let's consider each fossil fuel source

- Natural Gas
- Petroleum
- Coal

We'll take the US perspective

- Largely independent across each fossil fuel source

JOB CREATION

Does a push for a renewable energy transition create jobs?

It may create some.

But remember, our economy is dynamic.

Net effect is likely to be small.

JOB EFFECT

Do you think the effect of environmental regulation on jobs is big or small?

Economists usually find the answer is “not much”

What factors might influence the size of the job effect?

- Ability of firms to move location
- Ability of workers to move to other firms
- Size of effect of regulation
- Time scale

JOB LOSSES

Say a regulation causes a firm to layoff workers.

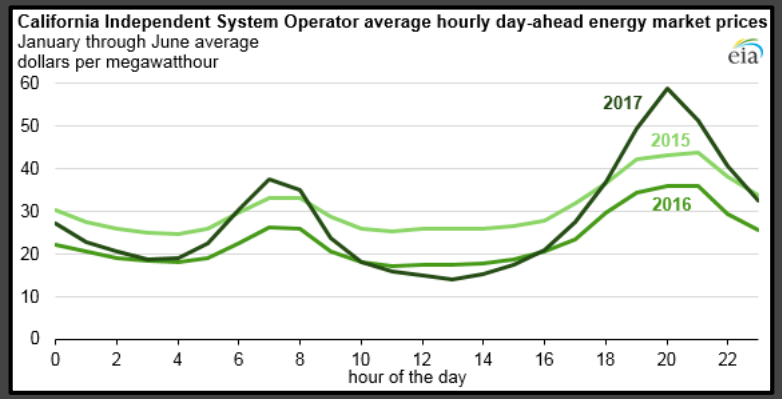
What happens to those workers? Are they unemployed forever?

Probably not.

Economy is dynamic. Workers can shift between firms.

Net job loss ≠ Gross job loss

LOWER ENERGY PRICES



If renewable energy can provide energy at a lower price, is there a need for regulation to accelerate adoption?

If the goal is economic efficiency, it is important that fuels be priced at their true cost.

Then lowest cost sources will be adopted.

CLEAN TRANSITION POLICIES

EXTERNALITIES

Fossil fuels are depletable resources

- Negative externality

Burning fossil fuels generates GHGs, driving climate change

- Negative externality

Development of innovative technologies

- Positive externality

WHAT IS THE OPTIMAL POLICY RESPONSE?

Scarcity cost of natural resources
- Property rights
- Pigouvian tax
- Permits

Climate change impacts
- Pigouvian tax
- Permits

Development of innovative technologies
- Pigouvian subsidy
- Patents

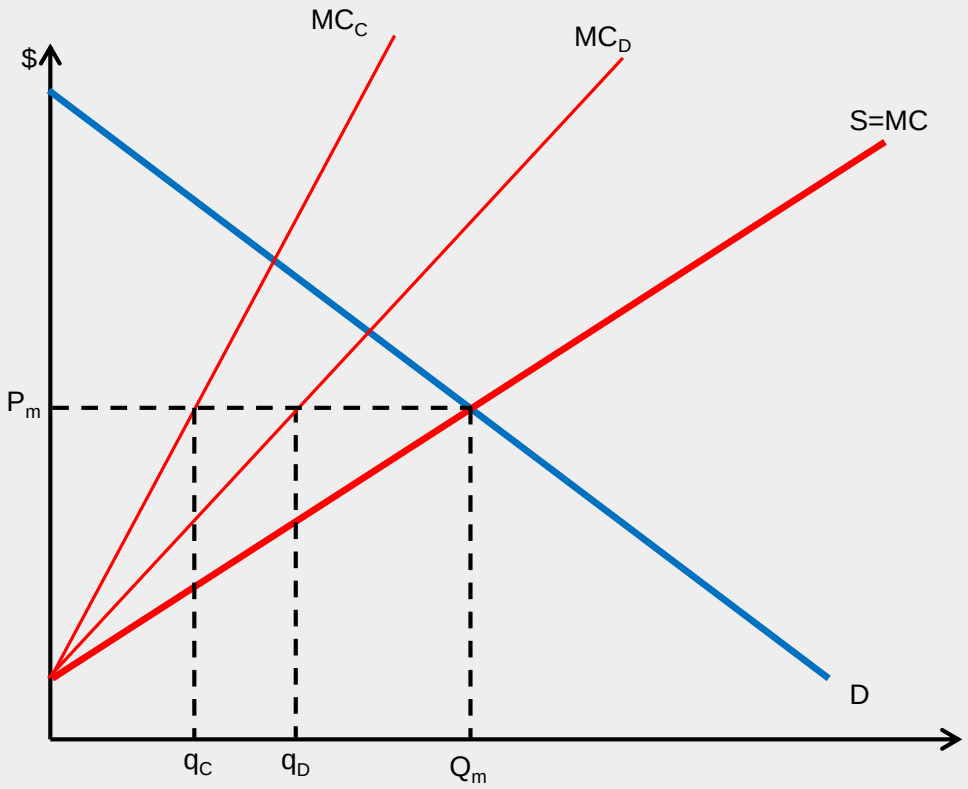
SECOND-BEST POLICY

As we've seen with climate change, often policy makers do not implement tax or cap-and-trade policies, instead opting for second-best policies for renewable energy adoption.

- Standards (e.g. RPS)
- Subsidies (e.g. ITC)

So let's again compare second-best policy to first-best policy.

TAXES VS. SUBSIDIES

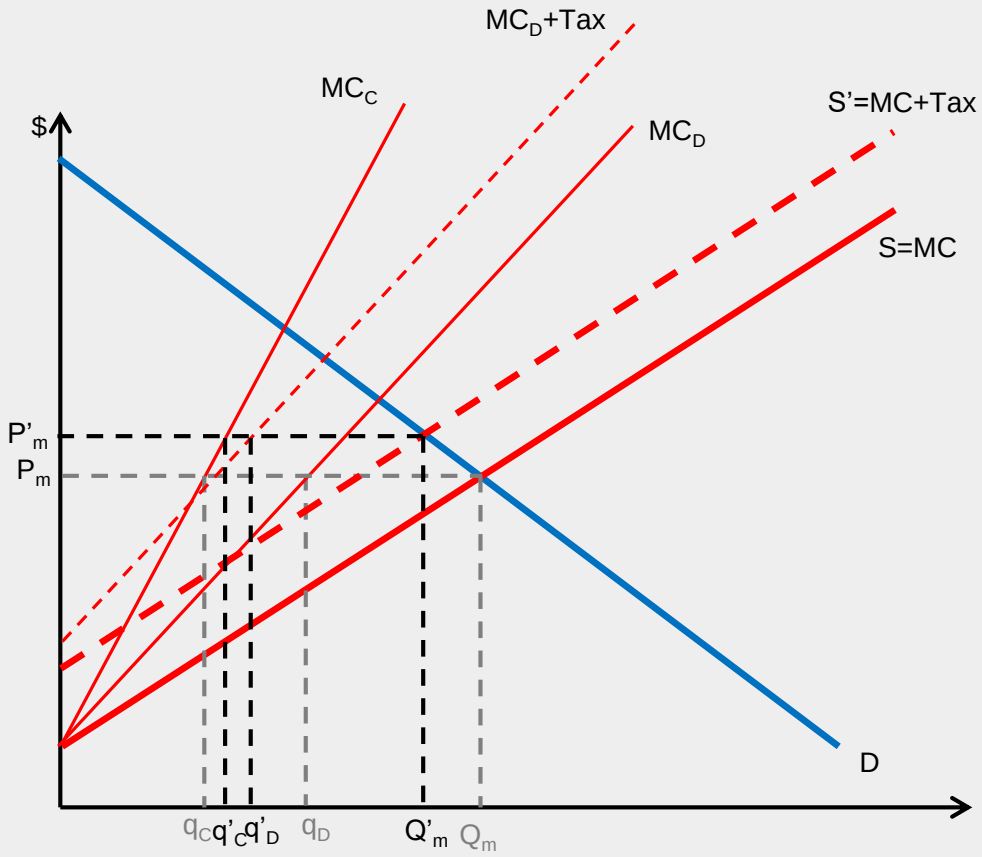


Consider the market for energy.

Two suppliers:
- Clean (renewable)
- Dirty (fossil fuel)

Let's compare outcomes when we tax the dirty industry vs. subsidizing the clean industry

TAXES VS. SUBSIDIES



Consider the market for energy.

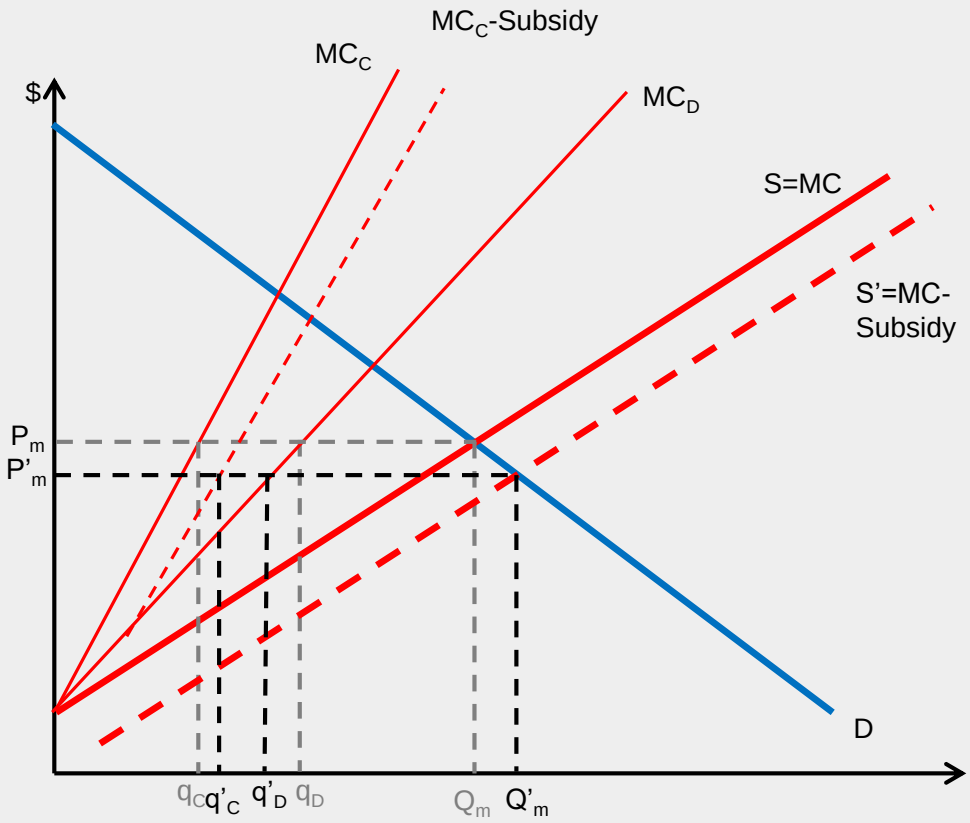
Two suppliers:

- Clean (renewable)
- Dirty (fossil fuel)

<u>Tax</u>

- Implement a tax on dirty energy
- Increases the price of energy
- Decreases total quantity of energy
- Decrease the quantity of dirty energy
- Increases the quantity of clean energy
- Raises tax revenues = q'_D*Tax

TAXES VS. SUBSIDIES



Consider the market for energy.

Two suppliers:

- Clean (renewable)
- Dirty (fossil fuel)

Subsidy (so q'_C same as tax)

- Implement a subsidy on clean energy
- Decreases the price of energy
- Increases the total quantity of energy
- Decrease the quantity of dirty energy
- Increases the quantity of renewable energy
- Subsidy cost of q'_C*subsidy

ATTENDANCE ACTIVITY

Consider the market for energy. Two suppliers:

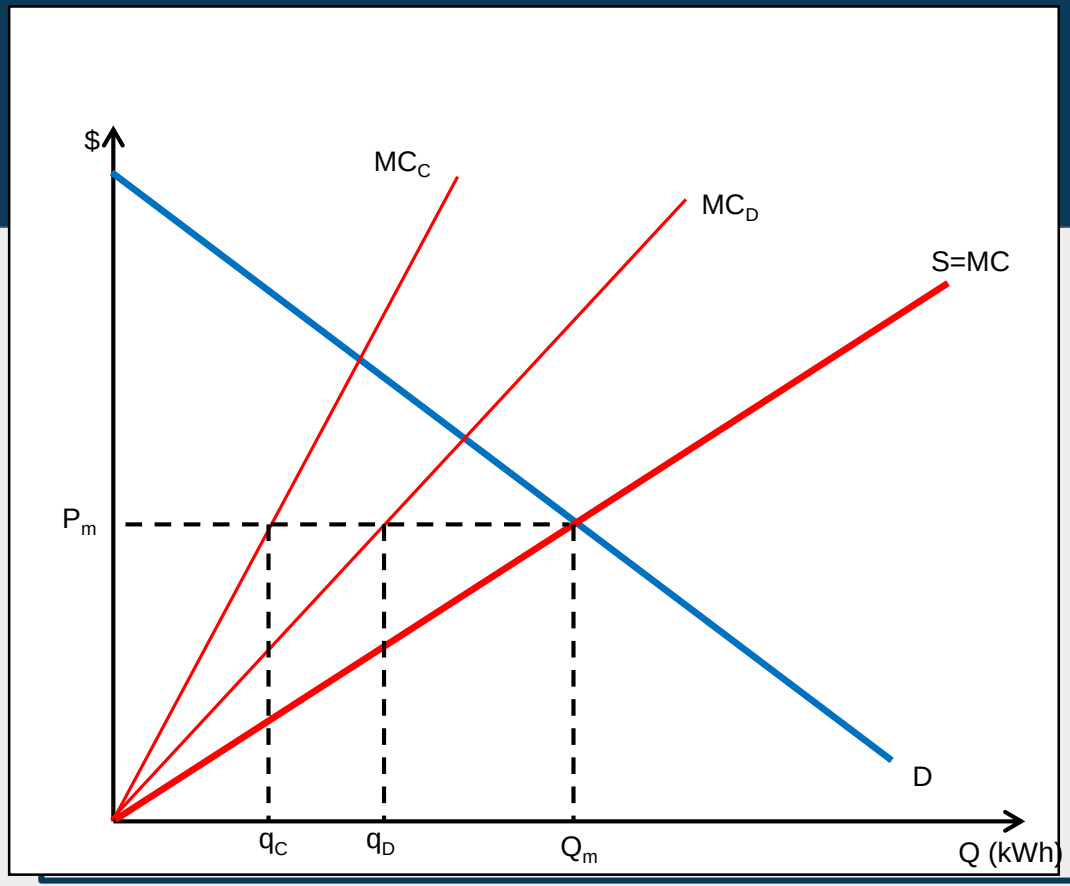
- Clean (renewable): MC=Q
- Dirty (fossil fuel): MC=0.5Q

Demand: MB=10-Q

What is the equilibrium quantity supplied by Clean and Dirty under:

1. No policy
2. $Tax_{Dirty} = 0.2Q$
3. $Subsidy_{Clean} = 0.2Q$

ATTENDANCE ACTIVITY



Consider the market for energy. Two suppliers:

- Clean (renewable): MC=Q
- Dirty (fossil fuel): MC=0.5Q

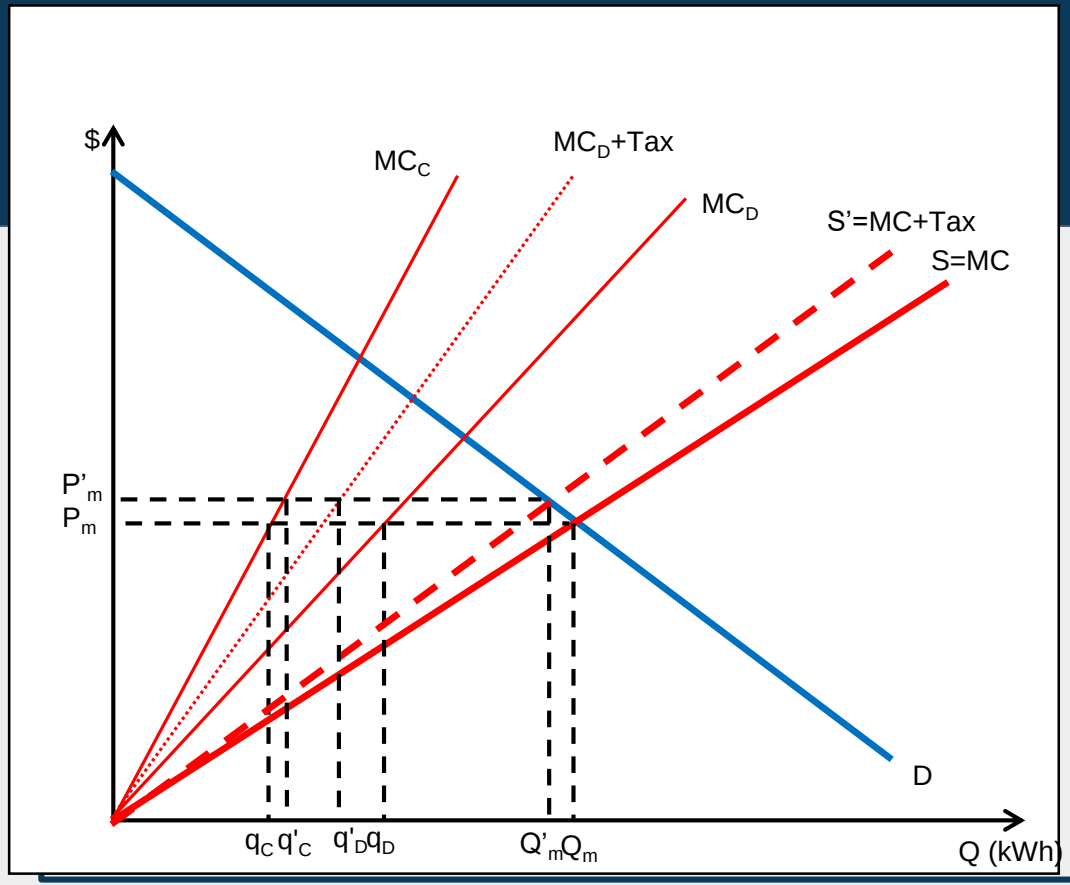
Demand: MB=10-Q

What is the equilibrium quantity supplied by Clean and Dirty under:

1. No policy

MC = 1/3Q = MB = 10-Q
$Q_m = 15/2$, $P_m = 5/2$
$Q_C = 5/2$, $Q_D = 5$

ATTENDANCE ACTIVITY



Consider the market for energy. Two suppliers:

- Clean (renewable): MC=Q
- Dirty (fossil fuel): MC=0.5Q

Demand: MB=10-Q

What is the equilibrium quantity supplied by Clean and Dirty under:

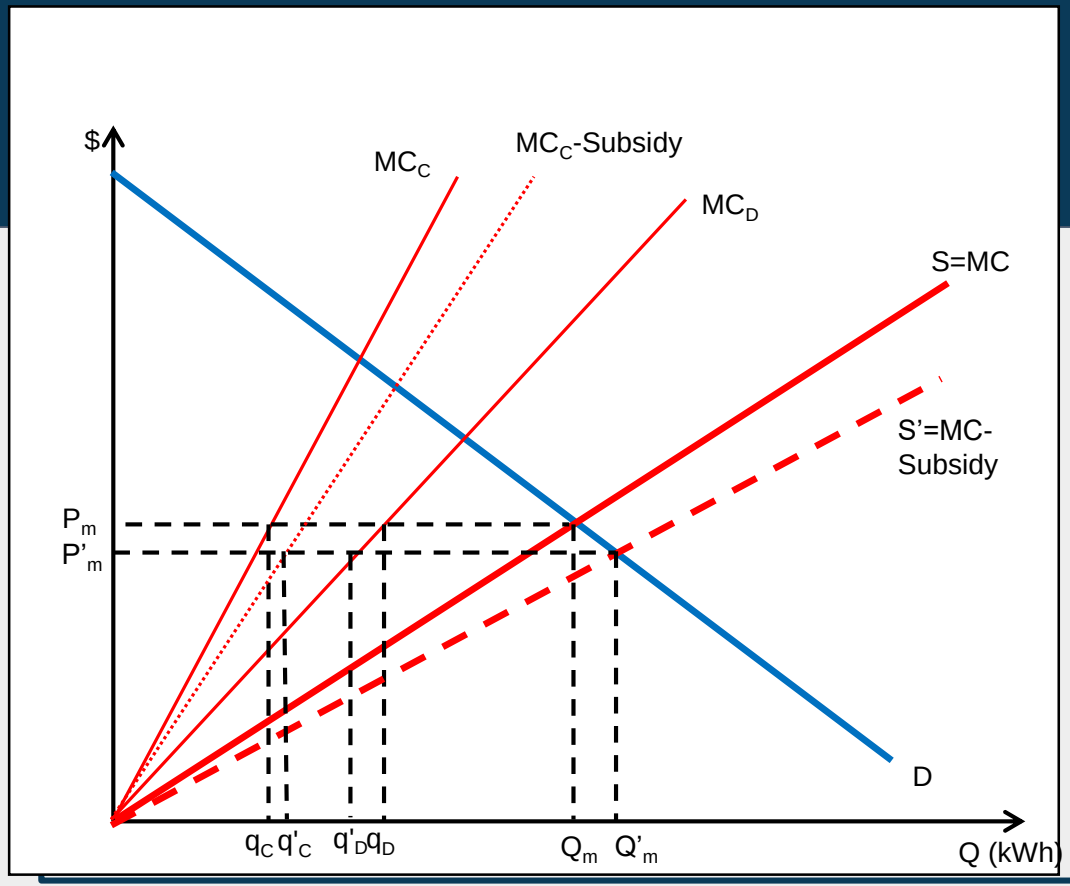
1. $Tax_{Dirty} = 0.2Q$

MC+Tax = 0.412Q = MB = 10-Q

$Q'_m = 7.08$, $P'_m = 2.92$

$Q_C = 2.92$, $Q_D = 4.16$

ATTENDANCE ACTIVITY



Consider the market for energy. Two suppliers:

- Clean (renewable): MC=Q
- Dirty (fossil fuel): MC=0.5Q

Demand: MB=10-Q

What is the equilibrium quantity supplied by Clean and Dirty under:

1. $Subsidy_{Clean} = 0.2Q$

MC-Subsidy = 0.308Q = MB = 10-Q
$Q'_m = 7.65, P'_m = 2.35$
$Q_C = 2.94, Q_D = 4.71$

SECOND-BEST POLICY

As we've seen with climate change, often policy makers do not implement tax or cap-and-trade policies, instead opting for second-best policies for renewable energy adoption.

- Standards (e.g. RPS)
- Subsidies (e.g. ITC)

So let's again compare second-best policy to first-best policy.

<u>Comparing tax vs. subsidy</u>

- Tax can achieve same level of clean energy at lower level of dirty energy
- Tax brings in revenues, whereas subsidy government must pay

PROBLEMS WITH TECHNOLOGY ADOPTION

PROBLEMS WITH TECHNOLOGY ADOPTION

We saw that putting a tax or cap-and-trade on dirty combined with subsidizing R&D is the optimal policy response for the clean energy transition.

Technological innovation (both development and **adoption**) will be important for a clean energy transition.

What are some practical problems around the **adoption** of clean technology.

We will talk about a few of these:

- Carbon Lock-in
- Energy Ladder
- Valley of Death

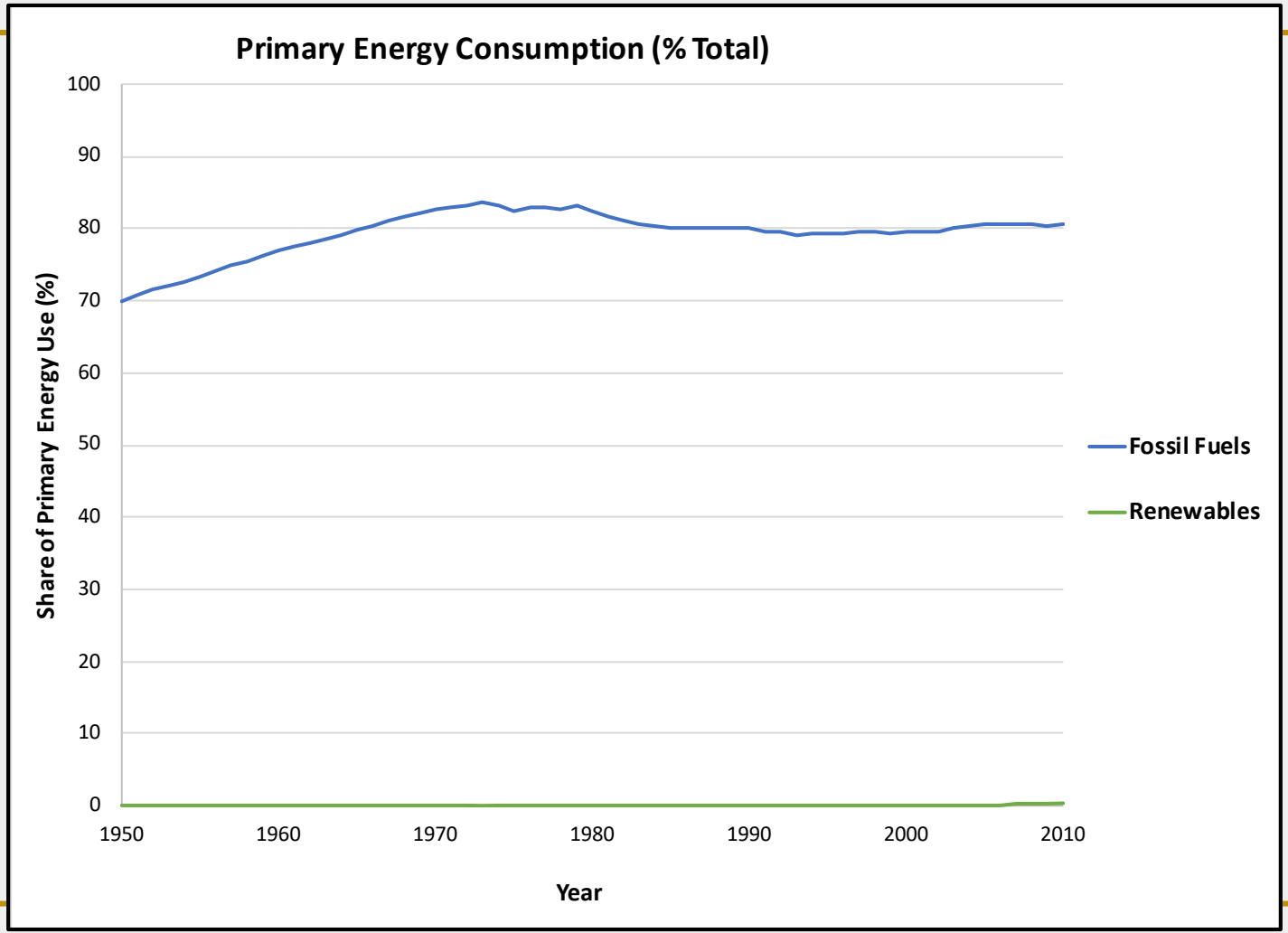
CARBON LOCK-IN

In developed economies, fossil fuels are by far the majority energy source.

This has been the case since as early as the 1600-1800s.

This has resulted in a *path-dependence* and increasing returns to scale.

- Developed countries technologies depend on fossil fuels, making it harder to break from a path dependence even if it appears economically optimal


Primary Energy Consumption (% Total)
Share of Primary Energy Use (%)
100
90
80
70
60
50
40
30
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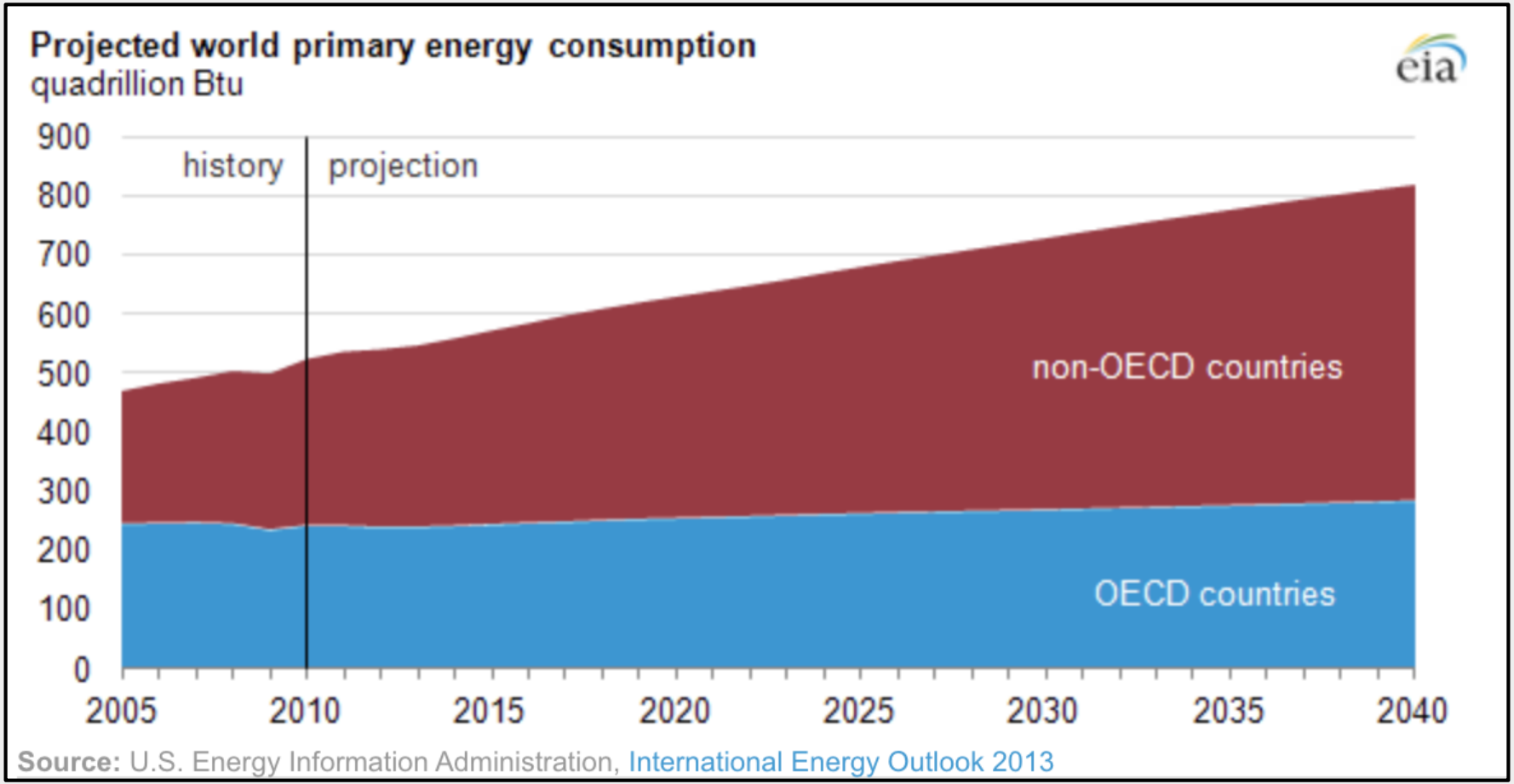
10
0
1950
1960
1970
1980
1990
2000
2010
Year
Fossil Fuels
Renewables

ENERGY LADDER

Energy consumption is projected to rise by around 50% in the next 25 yrs.

Much of this increased demand is expected to come from developing countries

- E.g. China, India


Projected world primary energy consumption
quadrillion Btu
eia
900
800
700
600
500
400
300
200
100
0
history
projection
non-OECD countries
OECD countries
2005
2010
2015
2020
2025
2030
2035
2040
Source: U.S. Energy Information Administration, International Energy Outlook 2013

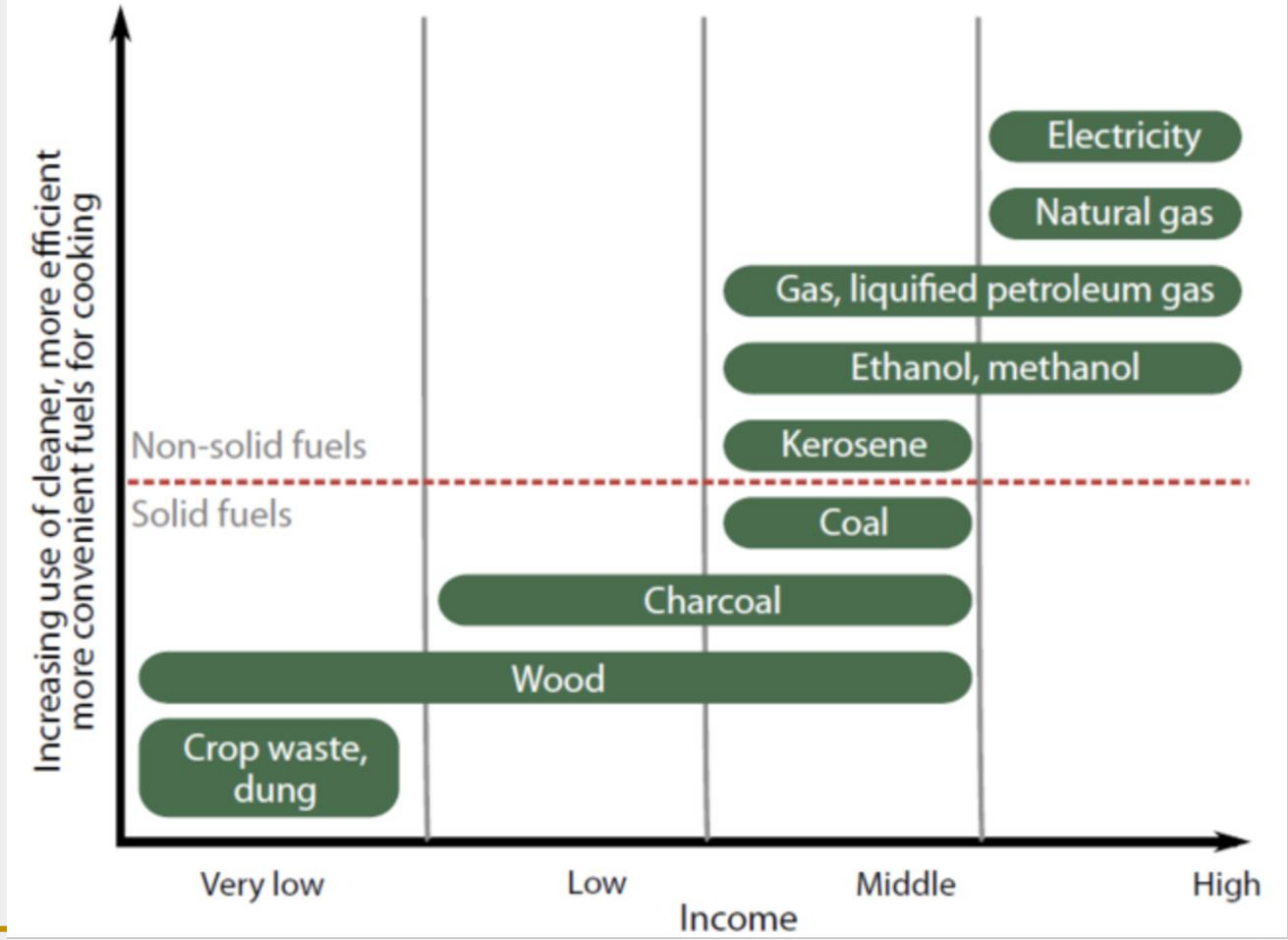
ENERGY LADDER

Energy consumption is projected to rise by around 50% in the next 25 yrs.

Much of this increased demand is expected to come from developing countries

- E.g. China, India

Some believe that changes in energy source follow an *energy ladder* that shows progressive energy sources based on income levels.



The Energy Ladder (Paunio, 2018)

ENERGY LADDER

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Much of this increased demand is expected to come from developing countries

- E.g. China, India

Some believe that changes in energy source follow an *energy ladder* that shows progressive energy sources based on income levels.

But they have an opportunity to avoid the *carbon lock-in* and *leap-frog* the ladder by adopting newer technologies.

LEAP-FROGGING EXAMPLE

Africa not just a mobile-first continent -- it's mobile only

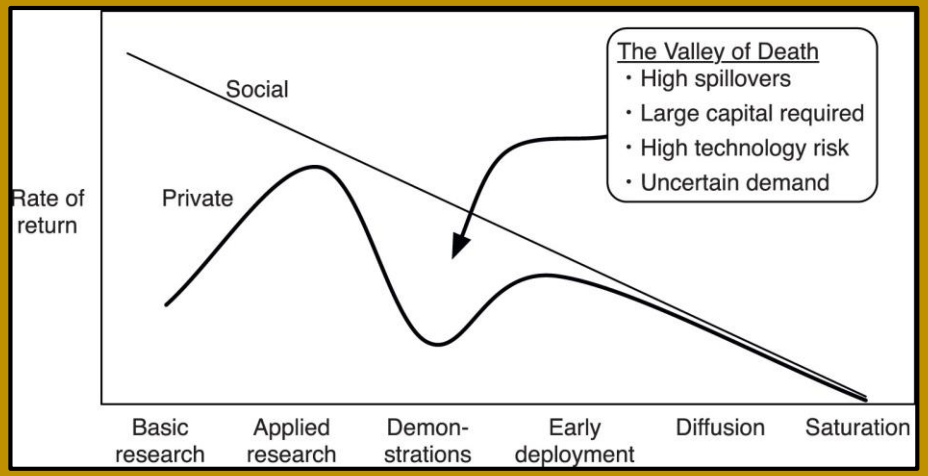
By Toby Shapshak, Special to CNN

Updated 12:07 PM ET, Thu October 4, 2012

In Parts Of Africa, Cell Phones Are Everywhere And Landlines Barely Exist

By Damon Beres

VALLEY OF DEATH



The process of innovation for a new technology can be broken into two stages: development and diffusion.

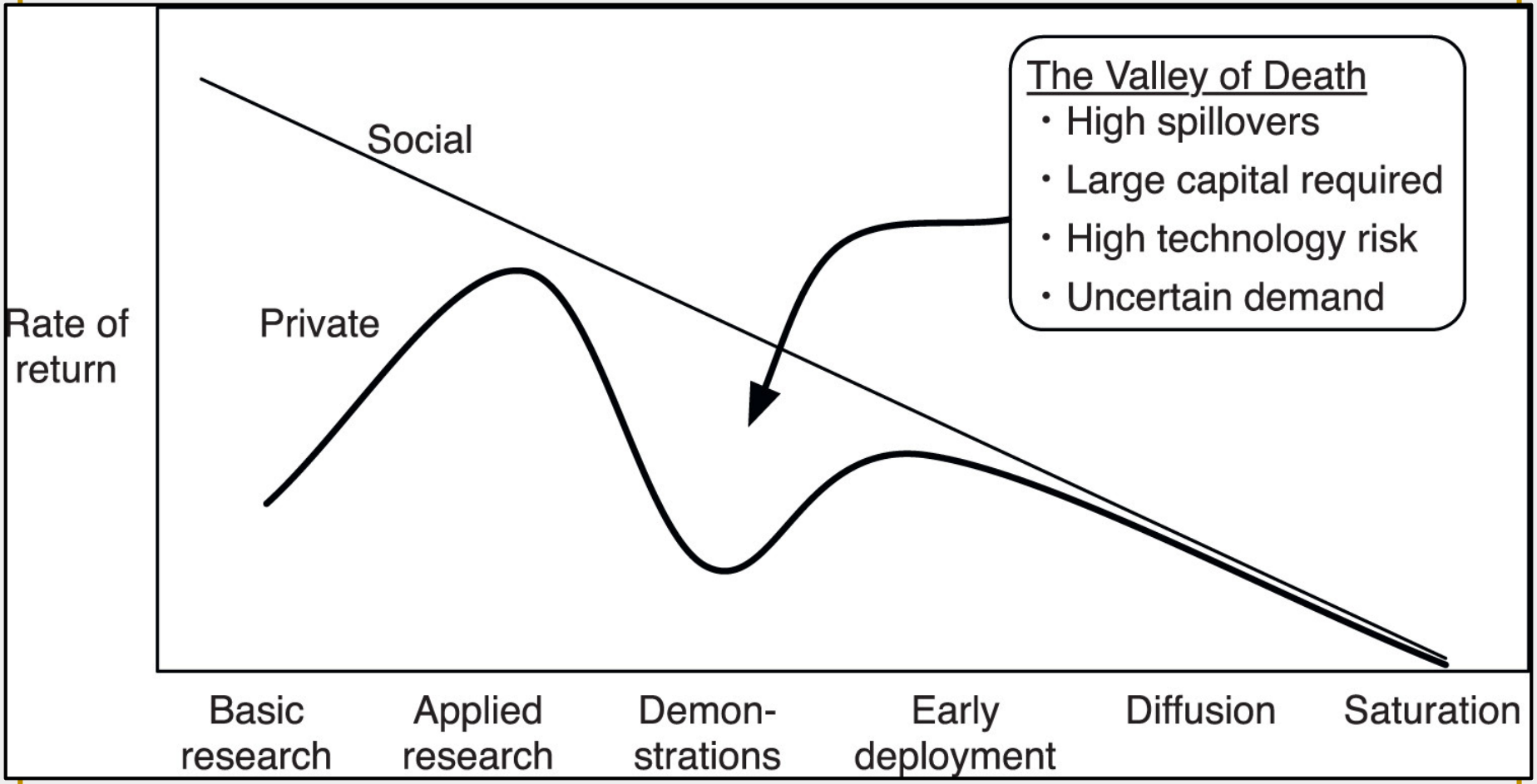
Between the two is what has been called the *valley of death*.

There is often large uncertainties around new technologies

- E.g. Cost, effectiveness, demand

During the *valley of death* the private returns to development drop, as reducing uncertainties is costly.

Valley of Death can stand as a barrier to the wide-spread adoption of new technologies.


Social
Private
Rate of return
The Valley of Death
• High spillovers
• Large capital required
• High technology risk
• Uncertain demand
Basic research
Applied research
Demon-strations
Early deployment
Diffusion
Saturation

PROBLEMS WITH TECHNOLOGY ADOPTION

Even if a new technology has been developed (perhaps with the support of R&D) subsidies and appears to be the economically optimal choice, there can still be barriers to wide-spread adoption.

- Carbon Lock-in
- Energy Ladder
- Valley of Death

LESSON OBJECTIVES

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History of Energy Use and Energy Transitions

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Analyze and Explain Current Push for Clean Energy Transition

03

Analyze Policies for Clean Energy Transition