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# **How effective is US R&D policy on clean energy?**

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**What is Research and Development?**

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Overview of Clean Energy R&D in the US

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# Research and development is about technology and innovation

- ▶ **Research and development** is about innovating – creating new products or services that are then adapted as **commercial “solutions” to an identified need**; “technology” is often described as the “product” of R&D
- ▶ In the context of **clean energy technology**, there is broad recognition of the “need” for less expensive, reliable, and renewable (environmentally benign) sources of electric power
- ▶ Why should there be a government policy (intervention) to support R&D?
  - ▶ Economists characterize R&D as a **public good**, returns from R&D understate **true social returns** from such investments, R&D will be **underprovided** by private sector/market
  - ▶ Spillover problem – **spillovers diffuse knowledge**; may reduce industry costs but can also dis-incentivize R&D investment
  - ▶ **Asymmetries of information** – financing obstacles
  - ▶ **Positive externalities** with respect to other national policies (export opportunities, support local labor and manufacturing sectors)

# R&D involves multiple and distinct stages in the process of bringing ideas to the market

## Basic and Applied Research

- **Basic research** – pursuit of scientific advancement without specific objectives; **applied research** – pursuit of scientific advancement with specific, practical objective
- Primarily conducted at **research laboratories**, administered by **industrial firms** (Lockheed Martin Corp, etc.) or by **universities** (California, Princeton, etc.) or by **non-profit organizations** (Brookhaven Science Association, etc.)
- Involves scientific research of **phenomena** and **processes, validation of results** and conclusions
- **Success** can be measured by a number of **patents** registered

## Development

- Technology is put into **practical** setting (e.g. flywheel principle was discovered by earliest humans, yet practical energy storage device based on flywheel was not developed until the 20<sup>th</sup> century)
- Largely conducted at **research laboratories** and **companies**, or even by **entrepreneurs**
- Involves **testing, trials, and experiments**
- **Success** is measured on whether concepts have been **proven**

## Commercialization

- Technology is packaged into a **product** for **sale** in the marketplace
- Largely undertaken by **companies**, with possible support from **specialized government agencies**
- Involves going through **manufacturing, packaging, and marketing**
- Success is measured on whether the new products are **competitive** in price and in utility with existing alternative products

## Diffusion

- Technology becomes **widespread** and **accepted**
- Largely undertaken by **companies**, and possibly **specialized government agencies** as well as **non-profit organizations**
- Process involves **innovation gatekeeping, spreading** of innovation, development of technology **clusters**, etc.
- Success is measured by the **infusion of private capital** as an indication of sufficiently large market size and profit margins

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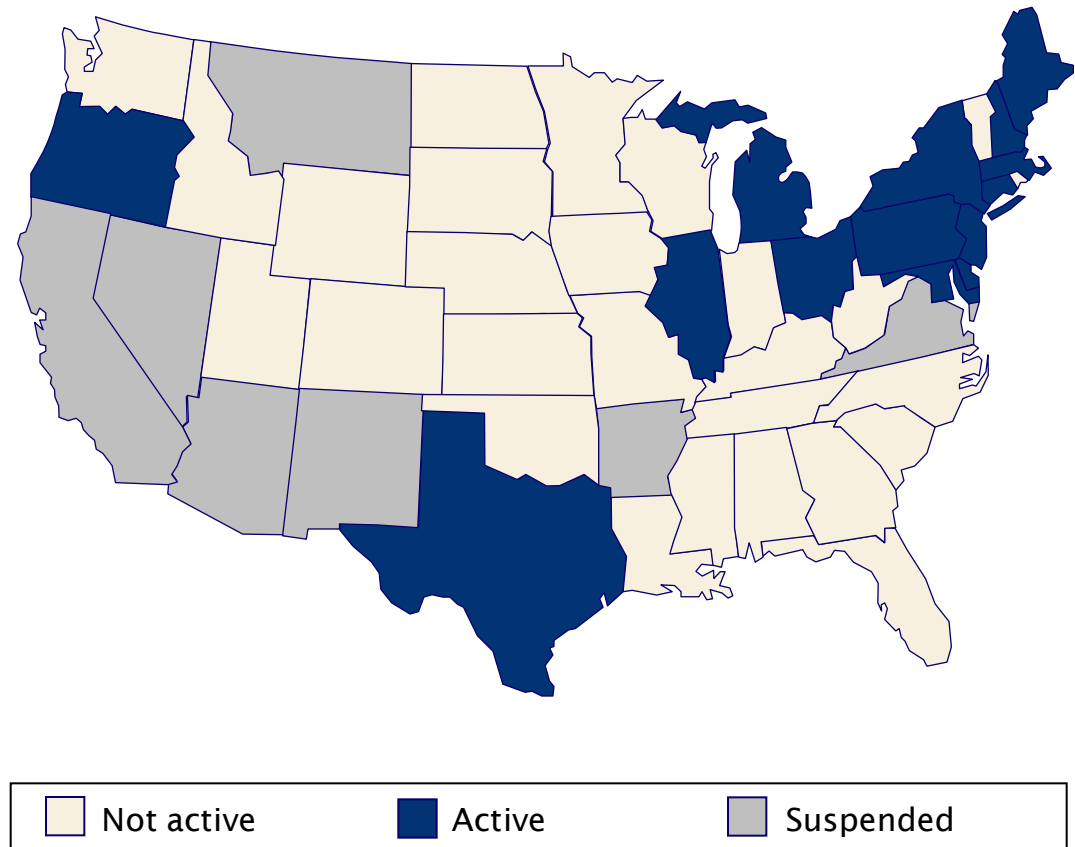
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Concluding Remarks

# Energy can be characterized as a deregulated industry

- ▶ Electricity sector transformed from a **cost-of-service industry** where generation competition occurs at the wholesale level and retail competition exists in 15 states and District of Columbia
- ▶ Seven states have suspended their **restructuring processes**, mostly following crises in other jurisdictions. However, even in many of these states, **IPPs co-exist with vertically integrated utilities** and therefore generation investment is driven by for-profit considerations
- ▶ In such a **deregulated, for-profit electricity generation environment**, will private sector invest sufficiently in R&D?

Status of Electricity Restructuring by State



Source: Energy Information Administration, December 2010

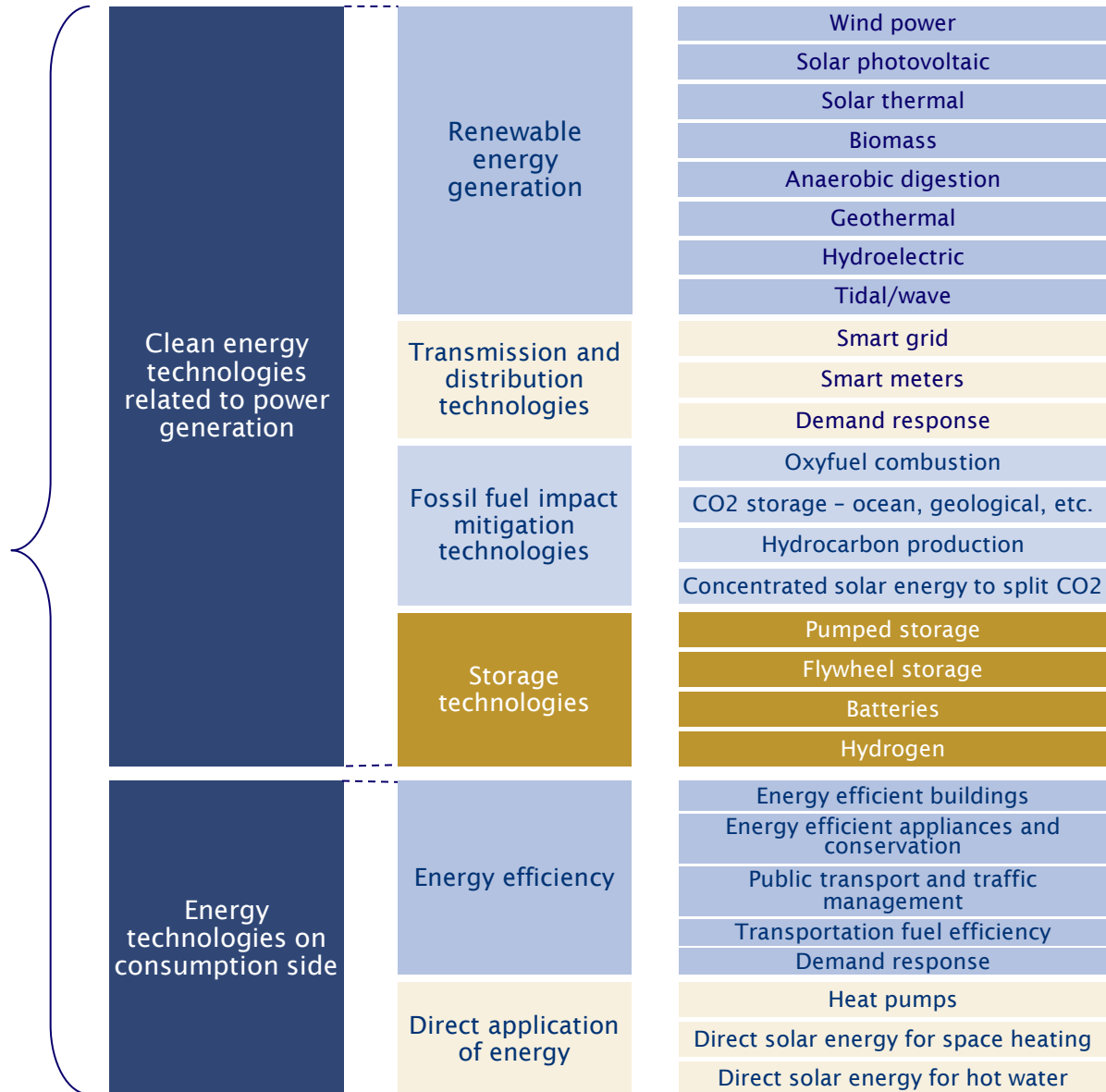


# Clean energy includes a variety of technologies, including variants on traditional thermal power production

## What is part of the “clean technology” vocabulary?

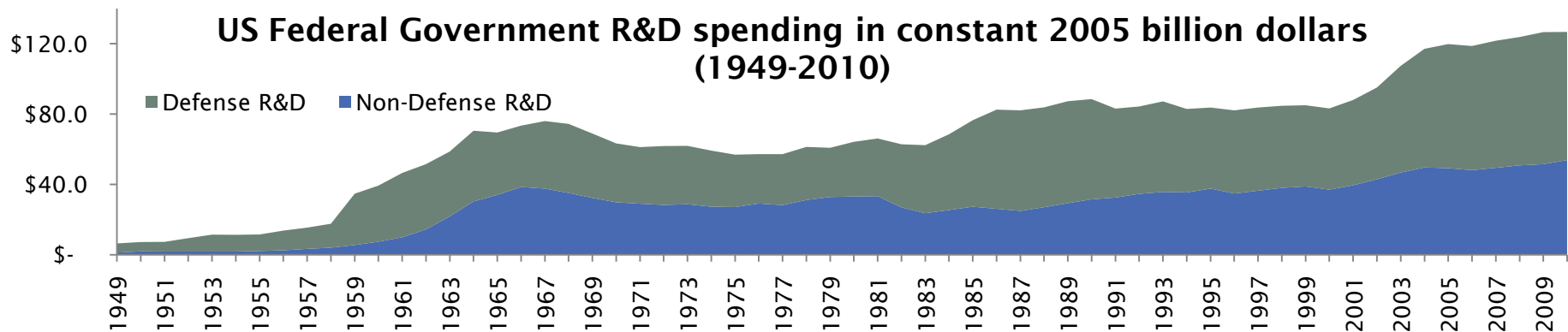
- ▶ Clean energy broadly includes all technologies and approaches aimed at reducing the use of - or even substituting - fossil fuel based power generation/energy consumption
- ▶ Currently available technologies may be categorized into different types\*
- ▶ There may be varying levels of ‘environmentally friendly’ technology. Nuclear is often argued to be representative of the “clean energy” cadre, but it is not environmentally benign
- ▶ Does new, more efficient gas also qualify as renewable?

\* List is not exhaustive



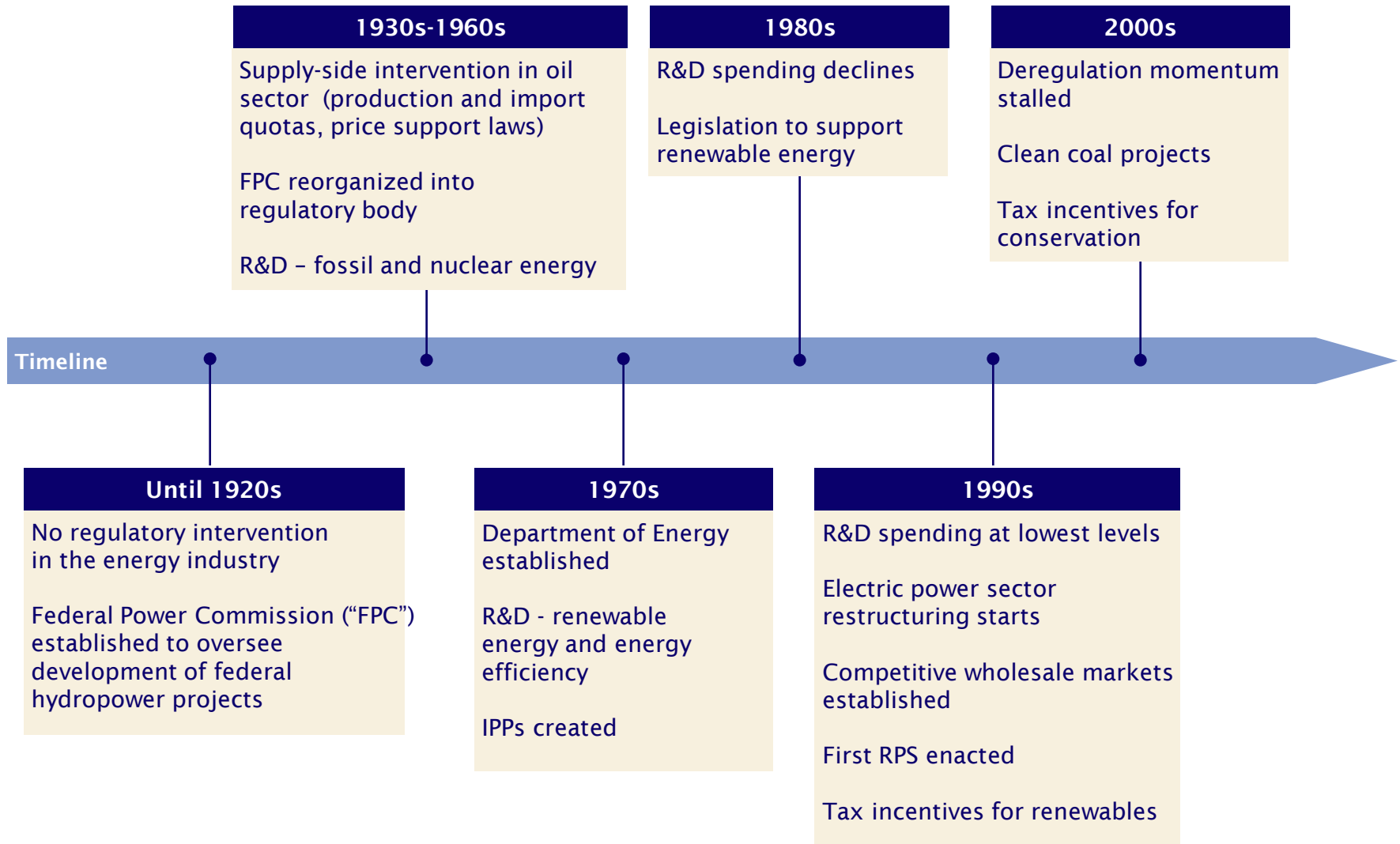
# US Federal government has supported R&D across multiple industries and sectors

- ▶ The **Departments of Defense and Energy** are the **largest funders of research and development** in the United States
  - Oldest military research lab was established in 1874 (Sandy Hook Proving Ground)
  - The Ernest Orlando Lawrence Berkeley National Laboratory of the Department of Energy was created in 1931, followed by establishment of 15 other research labs and centers
  - Military research initiatives created the first DOE laboratories in Los Alamos and Oak Ridge, which were transferred to the Atomic Energy Commission after the end of WWII (but continued to be privately managed or managed under the auspices of a university)
- ▶ Other R&D activities are supported and funded by the **Departments of Agriculture, Health and Human Services, Veteran's Affairs, Transportation, Treasury, National Science Foundation, NASA**, etc.
- ▶ **Renewable Energy Production Tax Credit** was introduced as part of Energy Policy Act of 1992 (starting at 1.5 cents per kWh, adjusted annually thereafter for inflation)



Source: *Historical Tables of Fiscal Year 2012 Budget of the US Government*. Office of Management and Budget of the Executive Office of the President of the US

# A review of the history of energy policy/regulation in the US highlights the event-driven nature of R&D budget trends and how the focus of R&D has evolved



# US Federal government supports clean energy technology development through a multitude of agencies – but focus appears to be on first stages of R&D cycle

Government bodies and institutions	Basic and applied research	Development	Commercialization	Diffusion
Department of Energy	<ul style="list-style-type: none"> <li>• Fusion energy sciences program</li> <li>• Fossil energy R&amp;D program</li> <li>• Unconventional fossil energy technologies</li> <li>• Hydrogen technology</li> <li>• Reactor concepts R&amp;D program</li> </ul>	<ul style="list-style-type: none"> <li>• Building technologies</li> <li>• Renewable technologies program (solar, wind, etc.)</li> <li>• Nuclear fuel cycle R&amp;D</li> <li>• Generation IV nuclear energy system</li> <li>• Fuel cell technologies program</li> </ul>	<ul style="list-style-type: none"> <li>• Nuclear loan guarantee program</li> <li>• Advanced technology vehicle manufacturing loan program</li> </ul>	<ul style="list-style-type: none"> <li>• Energy innovation hubs</li> </ul>
Department of Defense	<ul style="list-style-type: none"> <li>• Plasma fusion</li> <li>• Lightweight, flexible solar photovoltaics</li> <li>• Power projection technology</li> <li>• Nanoscale additives for novel fuels</li> </ul>	<ul style="list-style-type: none"> <li>• Wind lift power generator</li> <li>• Ultra low energy community systems</li> <li>• Advanced nuclear power systems</li> <li>• High efficiency fuel cells</li> <li>• Anaerobic digester</li> </ul>		
National Science Foundation	<ul style="list-style-type: none"> <li>• Science and Technology Policy Institute</li> <li>• Science and technology centers</li> </ul>			
Department of Agriculture			<ul style="list-style-type: none"> <li>• Biorefinery assistance program</li> </ul>	<ul style="list-style-type: none"> <li>• Biodiesel fuel education program</li> <li>• Rural energy for America program (loan guarantees, grants)</li> </ul>
National Aeronautics and Space Administration			<ul style="list-style-type: none"> <li>• Green aviation</li> </ul>	
Department of Transportation			<ul style="list-style-type: none"> <li>• Clean fuel grants</li> <li>• Energy efficiency grants</li> <li>• Hydrogen fuel vehicle safety</li> <li>• High speed rail</li> </ul>	
Small Business Administration				<ul style="list-style-type: none"> <li>• Regional innovation clusters</li> </ul>

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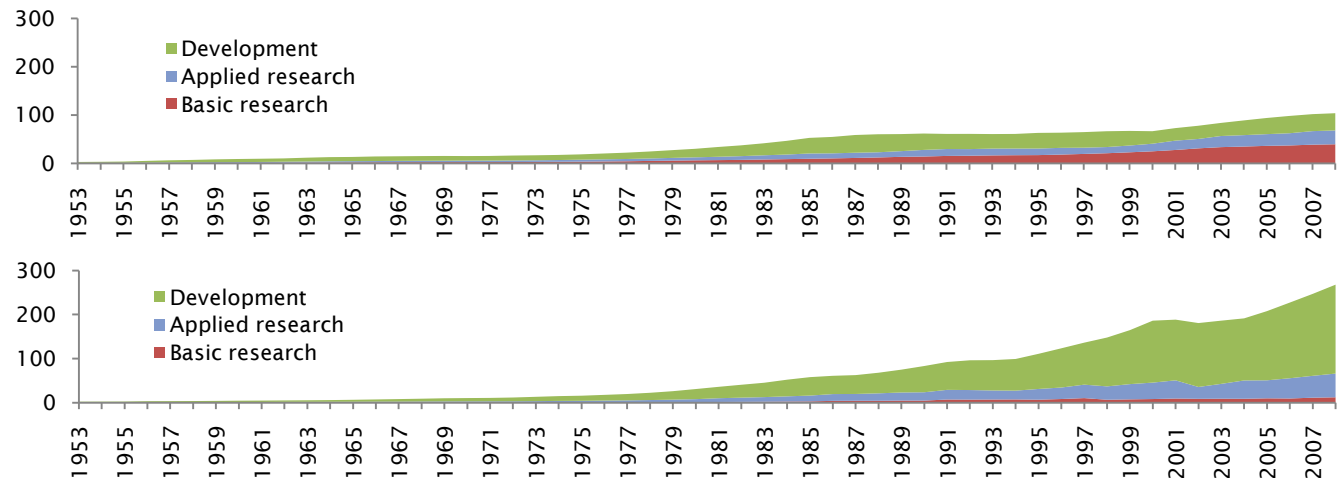
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Concluding Remarks

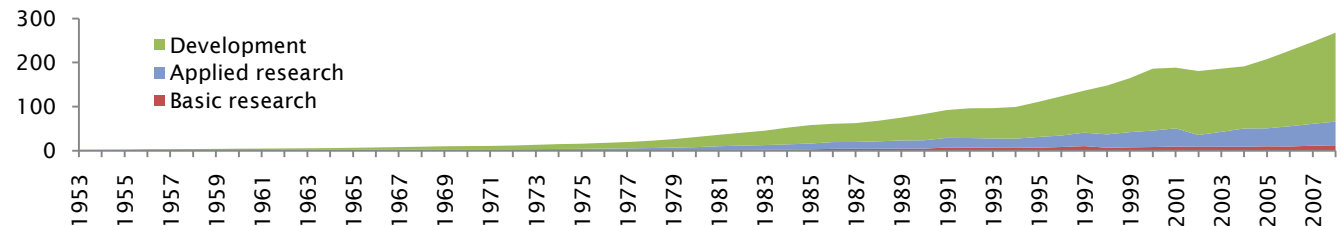
## Federal support for R&D is appropriate in industries where market forces cannot address current needs or adequately anticipate future needs

- ▶ Government support for R&D is needed wherever return on investment is uncertain and/or requires substantial resources (such as capital, land, human resources, technology, etc) and/or when the time horizon for investment return is too distant and in cases where the national interests/common benefit take precedence (notably defense, energy security, food security, and environment)
- ▶ Examples of areas/industries where federal funding is important include:
  - Health and medical research (including basic research in biochemistry, pharmaceuticals, medical research for military applications, biohazards, vaccines, etc.)
  - National defense (including military applications of clean energy research, etc.)
  - Space exploration (including basic and applied research in science, etc.)
  - Transportation (including public transit, clean fuel and energy efficiency research, etc.)
  - Agriculture (including resilient seeds and crops, fertilizers, pest management, etc.)
  - Environmental protection (including fuel, emissions, energy efficiency research, etc.)

Federal Government  
R&D (bln current \$)



Industry R&D (bln  
current \$)



Note: the above does not include commercialization spending as well as the state-level spending on RPS support programs

# Striking a balance of funding allocation across subject areas is difficult task: DOE R&D budget has recently increased allocations for clean energy technology

▶ **Between 1949 and 2010 US Federal Government spent 42% of its R&D budget on non-defense purposes**

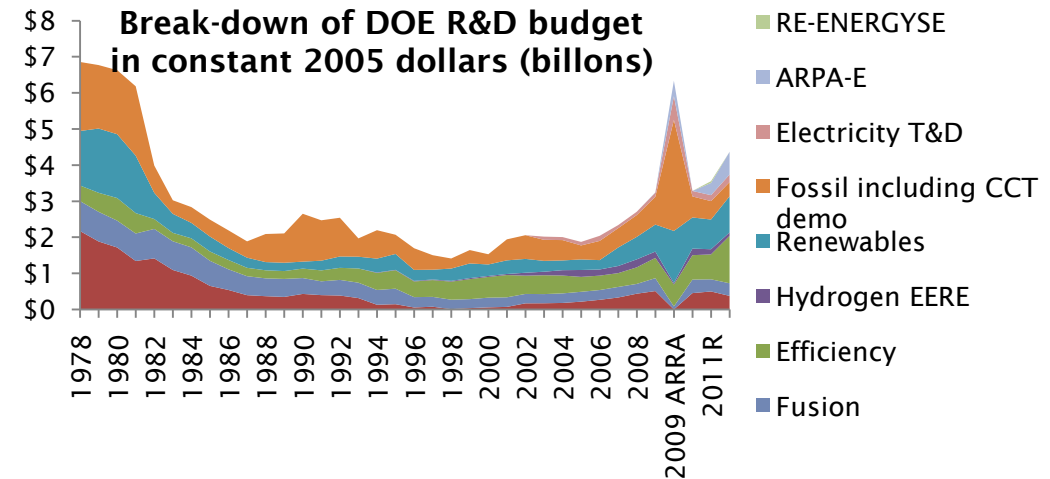
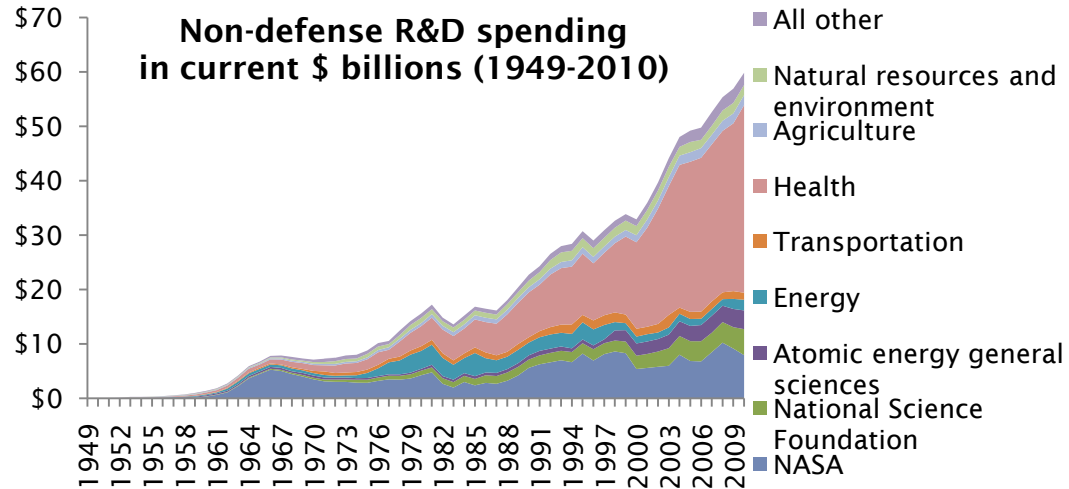
- 42% of non-defense R&D has been spent on medical research
- 22% of non-defense R&D has been spent on space exploration (NASA)
- 8% of non-defense R&D has been on energy research (including fossil and nuclear)

▶ **Between 1978 and 2010 DOE R&D budget allocated**

- 33% on fusion and fission research
- 29% for fossil fuel-related research
- 20% for renewables

▶ **In 2010 DOE requested**

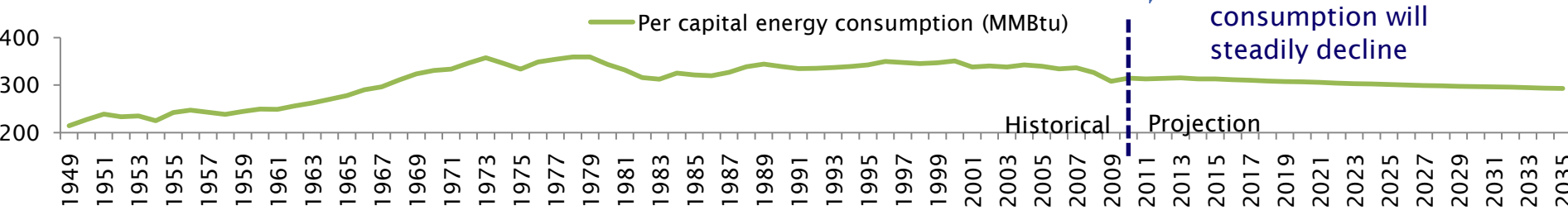
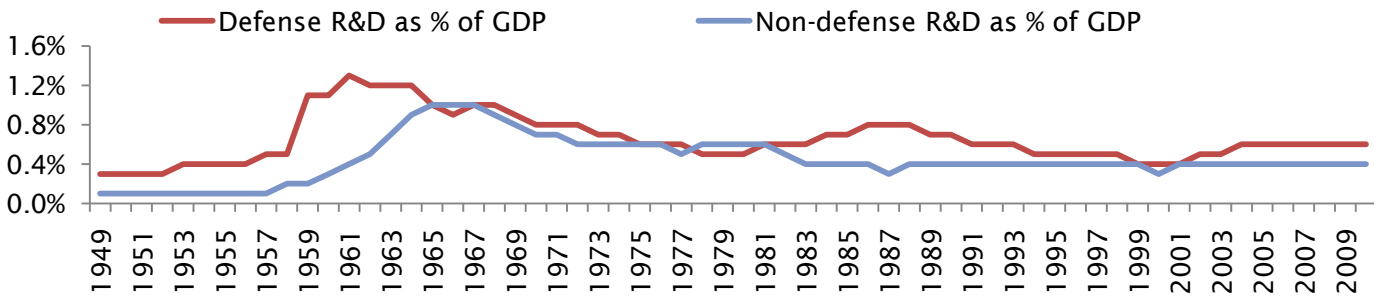
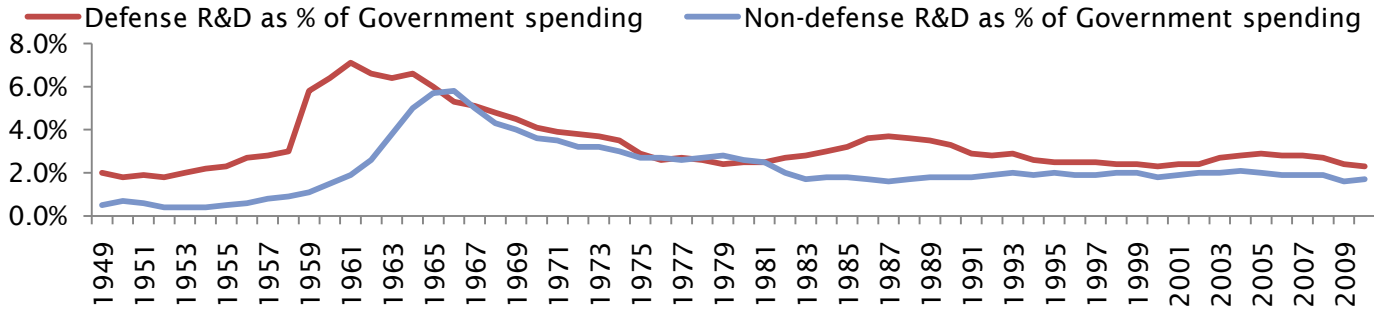
- 26% of its R&D budget for renewables research
- 25% for fusion and fission research
- 21% on energy efficiency



Source: *Historical Tables of Fiscal Year 2012 Budget of the US Government*. Office of Management and Budget of the Executive Office of the President of the US; Harvard University, John F. Kennedy School of Government, Belfer Center for Science and International Affairs. *DOE Budget Authority for Energy Research, Development and Demonstration Database*, March 2011



# Non-defense government R&D spending has been stagnant in the last four decades – hovering at around 0.5% of GDP



- ▶ Per capita energy consumption has dropped following the oil crises of '73 & '79
- ▶ While energy consumption reduction was prompted by oil price spikes and economic slowdown, the sustained reduction and stabilization of the growth rate was largely possible due to extensive R&D spending in the decade prior to the 1973 crisis
- ▶ EIA projects that per capita energy consumption will steadily decline

Source: *Historical Tables of Fiscal Year 2012 Budget of the US Government*. Office of Management and Budget of the Executive Office of the President of the US; Harvard University; Energy Information Administration. *Annual Energy Outlook 2011, Annual Energy Review 2010*.

Note: top two charts do not include R&D spending allocated through ARRA

## R&D for clean energy technology should play larger role; defense and space exploration spending still proving beneficial

- ▶ While the effect of global warming may be debated, the **looming shortage of energy sources** to satisfy growing demand is inevitable
- ▶ Clean energy technology research can be viewed as a **fiscal instrument** in the short-term; it also can lead to long-term impact on society and economy through **technological innovation, new products, increased efficiency of resource utilization and energy security** that will have spill-over effect on other industries
- ▶ Much of the current **US competitive advantage** is owed to **defense and space exploration research and developments** that have resulted in many discoveries and technologies that, although unintended, were important in their impact on society and economy
  - Satellite communications (GPS navigation, television, weather forecast, safe air travel, retail banking, etc.)
  - Internet protocol for efficient data dissemination that found a multitude of uses
  - Advanced research in radiation technology (cancer treatment and diagnostics)
  - Overall, NASA documented over 1,500 “spin-off” success stories across health and medicine, transportation, public safety, consumer goods, environmental and agricultural resources, computer technology and industrial productivity
- ▶ While **space exploration** was expected to provide benefits to the society, the **extent and range of impacts was uncertain** at the start of the space program
- ▶ Clean energy research and development, on the other hand, is explicitly aimed at addressing **immediate and present issues of depleting resources, pollution, energy security and economic slowdown**
- ▶ However, unlike nationally focused space exploration and defense programs, **state R&D support for clean energy technology** is also **significant** – for example, RPS programs help in the commercialization stage of new clean energy technologies

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## Many reports suggest that US may be falling behind countries such as China and Germany in promoting clean energy development

- ▶ In the following slides, we review the clean energy policies of the US, China, and Germany, and provide examples of indicators for relative success, in order to answer the following questions:
  - *Is the US government falling behind in clean energy R&D spending? (supply-push)*
  - *How do US policies help promote clean energy commercialization compared to those in China and Germany? (demand-pull)*
  - *What policies does the US have to promote supporting infrastructure for clean energy in comparison to those in China and Germany?*
  - *Has the US been more successful domestically in terms of installing renewable generation and attracting investment?*
  - *Has the US been more successful globally in terms of manufacturing to support clean energy and exporting clean energy technology?*

# US government leads in terms of clean energy R&D spending and clean energy patents registration

- ▶ According to IEA, the US is significantly ahead of China and Germany in terms of government R&D spending, while the private sectors play more important roles in clean energy R&D in China and Germany
- ▶ China currently lags behind the US and Germany in R&D spending and has therefore recently established a national R&D plan that promotes indigenous innovation

	US	China	Germany
<b>Key national programs</b>	National labs, ARPA-E, Energy Innovation Hubs, Frontier Research Centers	863 and 973 programs	High-Tech Strategy, ERP Innovation program
<b>Funding</b>	Primarily government funded, low private sector investment	Primarily government funded with policies to stimulate private sector R&D investment and public-private collaboration	Private R&D exceeded government R&D (as of 2001)
<b>Innovation policy</b>	No long-term national innovation policies	National R&D plan with quantifiable targets to increase indigenous innovation	High-Tech Strategy by 2020, 6th Energy Research Program
<b>Government clean energy R&amp;D spending (\$ million, 2008)<sup>1</sup></b>	2,455	45	459
<b>Government clean energy R&amp;D spending (% of GDP, 2008)<sup>2</sup></b>	0.02%	0.00%	0.01%
<b>Clean energy patents granted in the US (2002-2011 Q2)<sup>3</sup></b>	4,895	40	761
<b>Clean energy patents granted in each country (1976-2010)<sup>4</sup></b>	~25,400	~5,300	~5,800

Source: 1. IEA. *Global Gaps in Clean Energy RD&D* (excludes basic research unless it is clearly oriented towards the development of energy technologies); 2. GDP from EIU Country data; 3. The Cleantech Group at Heslin Rothenberg Farley & Mesiti P.C.; 4. *Who Owns Our Low Carbon Future? Intellectual Property and Energy Technologies: A Chatham House Report*. Bernice Lee, Ilian Iliev and Felix Preston

# US policy on commercialization and diffusion of clean energy technology development depends more on the state-level support, while China and Germany rely more on the central government

- ▶ China and Germany's national R&D policies focused on various mechanisms to improve commercialization and diffusion stages of R&D – for example, subsidies (Feed-in Tarriff) and government-backed low cost financing
- ▶ US lacks comprehensive clean energy technology financing support. But does the US balance the lack of government support with private sector? Is private sector support sufficient?

	US	China	Germany
<i>Policy</i>			
<b>1. Renewable target</b>	No national level target; currently 29 states and D.C. have binding targets	15% of total consumption by 2020 (potentially revising this figure to 20%)	35% of total consumption by 2020 (50% by 2030); EU target 20% by 2020
<b>2. Carbon reduction target</b>	No binding target	binding target of 40-45% reduction by 2020 compared to 2005 levels	binding target of 40% reduction by 2020 compared to 1990 levels; EU target 20% by 2020
<b>3. Energy efficiency target</b>	No national level target; currently 22 states have Energy Efficiency Resource Standards	16% reduction from 2011-2015	20% reduction by 2020 compared to a business-as-usual development (EU wide target)
<i>Financing support (resulting from policy)</i>			
<b>1. REC/FIT</b>	Mostly REC (only in states that have binding targets)	National FIT, competitive tendering	National FIT
<b>2. Tax benefits</b>	Production Tax Credit for wind and Investment Tax Credit for solar	Reduced value added tax and corporate income tax for certain renewable	Partial tax exemption for biofuel; VAT exemption for commercial PV providers
<b>3. Special financing</b>	DOE loan guarantee program	Government owned banks, financial institutions heavily involved; loan interest subsidies available	Low interest loans provided by government owned KfW

# All three countries have been focused on promoting infrastructure development that supports clean energy development, with China and Germany providing more consistent policies at national level

- ▶ The Chinese government is heavily involved in renewable manufacturing by holding interests in renewable manufacturers through various government owned banks. The German manufacturing sector has led by virtue of the first mover advantage (but primarily in the private sector). In the US, the government tends to have minimal involvement outside of more simple 'promotion' strategies of US manufacturing abroad
- ▶ The Chinese and German governments have both realized the importance of grid development on a national level in renewable build out and have taken steps to promote such development. However, China is far behind in the commercial realization of such goals – many completed wind generators are not operable and it may take 3-4 years for interconnections to be completed
- ▶ In the US, the ARRA provided significant funding for transmission and smart grid development; however, there is no permanent national policy in place

	US	China	Germany
<i>Supporting infrastructure development</i>			
<b>1. Manufacturing infrastructure</b>	Oregon solar industrial cluster; wind manufacturing clusters concentrate in the Midwest	Tianjin: largest wind industrial cluster (annual capacity 5.6 GW); Wuxi: largest solar industrial cluster (home to Suntech with annual capacity of 1 GW)	Solar valley; wind technology clusters in northwest Germany
<b>2. Grid development</b>	ARRA funding for transmission and smart grid (no permanent national policy)	Grid connection remains an issue. Strong and Smart Grid Plan issued by State Grid Corp targets at ultra high voltage transmission development to support remote renewables (target completion by 2020)	Network Expansion Acceleration Act (identified needs and called for uniform federal planning and approval)

# China and Germany appear to have built more renewable generation and attracted more clean energy investment domestically

- ▶ **The benefit of clean energy investment is not limited to the direct investment; there are potential linkages with other sectors**
- ▶ **Multipliers can help establish secondary and tertiary benefits of investment on the local economy**
  - For example, considering a multiplier of 3.19 for the construction sector in the US as a proxy for indirect affects of investment<sup>1</sup>, the total economic impact of \$34 billion of clean energy investment could create benefits of over \$100 billion
  - Given these significant benefits, China had committed in its national plan to put 2.5% of GDP annually into R&D

	US	China	Germany
<b>Renewable capacity (GW, 2009)<sup>2</sup></b>	138	214	40
<b>Renewable capacity (% of total capacity, 2009)<sup>2</sup></b>	14%	24%	27%
<b>Renewable generation (TWh, 2009)<sup>2</sup></b>	381	599	95
<b>Renewable generation (% of total generation, 2009)<sup>2</sup></b>	9%	16%	16%
<b>Total clean energy investment (\$ billion, 2010)<sup>3</sup></b>	34	54	41
<b>Total clean energy investment (% of GDP)</b>	0.23%	0.93%	1.25%

Source: 1. BEA; 2. Energy Information Agency (USA), China Electricity Council, Federal Ministry of Economics and Technology (Germany). Note that it includes hydro, geothermal, wind, solar and biomass; 3. Pew Center. *Clean Energy Markets: Jobs and Opportunities*, July 2011 Update. Note that stimulus funding is included.

## All three countries encourage export of clean energy technology, with Chinese companies leading the renewables generation technology league tables

- ▶ Chinese companies dominate the top ten PV module suppliers and top ten wind turbine manufacturers
- ▶ Although certain US manufacturers, such as First Solar and GE, still ranked at the top of the leader board, their rankings have been declining

	US	China	Germany
<b>Export policy</b>	Renewable Energy and Energy Efficiency Export Initiative to remove financing obstacles, improve international market access and enhance information to link buyers and sellers	Limit export of rare earth materials that are necessary for solar panel and wind turbine manufacturing; various forms of clean energy technology export support (such as financing, insurance, export credit)	Renewable Energy Export Initiatives, facilitating business contacts between companies from Germany and abroad (dedicated B2B website)
<b>PV module supplier rankings top ten (based on 2010 shipments)<sup>1</sup></b>	Two companies ranked #2 and #8	Five companies ranked #1, #4, #5, #9 and #10	One company ranked #10
<b>Wind turbine supplier rankings top ten (2010)<sup>2</sup></b>	One company ranked #3 (total 10% of global market)	Three companies ranked #2, #4, #7 and #10 (total 32% of global market)	Two companies ranked #5 and #9 (total 12% of global market)
<b>Clean energy technology export (\$ billion, 2004-2008)<sup>3</sup></b>	\$7.7	\$22.7	\$19.6

Source: 1. IMS Research. *PV Modules 2010 Top Ten Rankings* Released by IMS Research; 2. BTM Consulting; 3. WWF. *Getting Back in the Game*.

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**Concluding Remarks**

# Key Observations and Concluding Remarks (Questions for further study)

- ▶ Do we need government intervention/support for clean energy technology R&D?
  - ▶ Profits associated with patents alone not sufficient to motivate new technology; presence of patents may dull the last stage of R&D cycle – the **diffusion process**
  - ▶ Where should government support be focused? China and Germany have been more active in supporting the **commercialization stage**
  - ▶ Does government support for R&D investment **displace (substitute for) or add to (complement) private investment**? How do commercially-viable technologies get weaned off public support?
  - ▶ In addition to cost, how great of a role does the **constancy and dedication of government** play?
- ▶ What instruments work best? No ‘one size fits all’ solution
  - ▶ Many empirical studies have negatively rated tax policies, but PTCs are credited with spurring wind development in the US, as well as grinding it to a dead halt when extensions of PTC legislation becomes uncertain or close to expiration
  - ▶ Feed-in-tariffs with high tariffs create the **economic incentive**, but at what cost? Do they **over-incentivize**?
  - ▶ How do we **consistently integrate state and federal policies**?
- ▶ How do clean energy R&D investment policies interact with other government policies?
  - ▶ R&D also known as **intellectual capital** – economic growth is the result of human, physical and intellectual capital
  - ▶ How does the US **leverage clean energy technology R&D policies** for overall economic growth? Needs to proceed cautiously and carefully – too many instruments and they may ‘cancel out’ each other