Navigating the Roadmap for Clean, Secure and Efficient Energy Innovation

SET-Nav
Strategic Energy Roadmap

Evaluating the EU's Energy Innovation System

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OBJECTIVE

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- To evaluate the balancedness and consistency of directed innovation activity in the EU with the priority areas set out in the Strategic Energy Technology (SET) Plan

No.	SET Plan 6 Priorities	SET Plan 10 Action Plan
1	**No.1 in Renewables (RE)**	Performant renewable technologies integrated into the system)
		Reduce costs of technologies
2	**Smart EU Energy System with consumers at the centre (SG)**	New technologies & services for consumers
		Resilience & security of energy system
3	**Efficient Energy System (EE)**	New materials & technologies for buildings
		Energy efficiency for industry
4	**Sustainable Transport (EV, Biofuels)**	Competitive in global battery sector (e-mobility)
		Renewable fuels
5	**Carbon Capture and Storage (CCS)**	Carbon Capture and Storage
6	**Nuclear Safety (NS)**	Nuclear Safety

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USE INDICATORS TO ANALYSE BALANCE IN SET PLAN PORTFOLIO

- **Strategic Energy Technology (SET) Plan (EC, 2008)**
  - SET Plan was launched to provide strategic energy planning and coordination of energy research & innovation activities within the EU.

- **Achieving these targets requires the following changes (EC, 2015)**
  - SET Plan management firmly rooted in the Energy Union
  - Strengthened cooperation: opening and widening to new actors
  - More joint actions
  - Transparency, indicators and periodic reporting
  - Monitoring and knowledge sharing

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Economics of Energy Innovation

- Well-designed environmental regulations can induce innovations that help improve firm's competitiveness (**Porter** and van der Linde, 1991).
- **Market-based regulation** creates incentives for dynamic improvement (Popp, 2003).
- Both **energy prices** and the quality of existing knowledge have strongly significant positive effects on innovation (Popp, 1999).
- An inverted-U relationship exists between **competition** and innovation (Aghion et al., 2005).
- **Policy uncertainty** negatively affects innovation activity.

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Systemic Perspective on Energy Innovation

- **National Innovation System (NIS)**: " .. the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." (Freeman, 1987).

- **Technology Innovation System (TIS)**: structural elements of innovation system and analyse actors, institutions, and networks that affect a specific technological development (Hudson, Winskel, & Allen, 2011).

- **Functional Innovation System (FIS)**: "functions" of innovation system as a critical determinant of analysing processes of energy technology innovation (Hekkert & Negro, 2009; Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008).

A SYSTEMS PERSPECTIVE ON ENERGY INNOVATION

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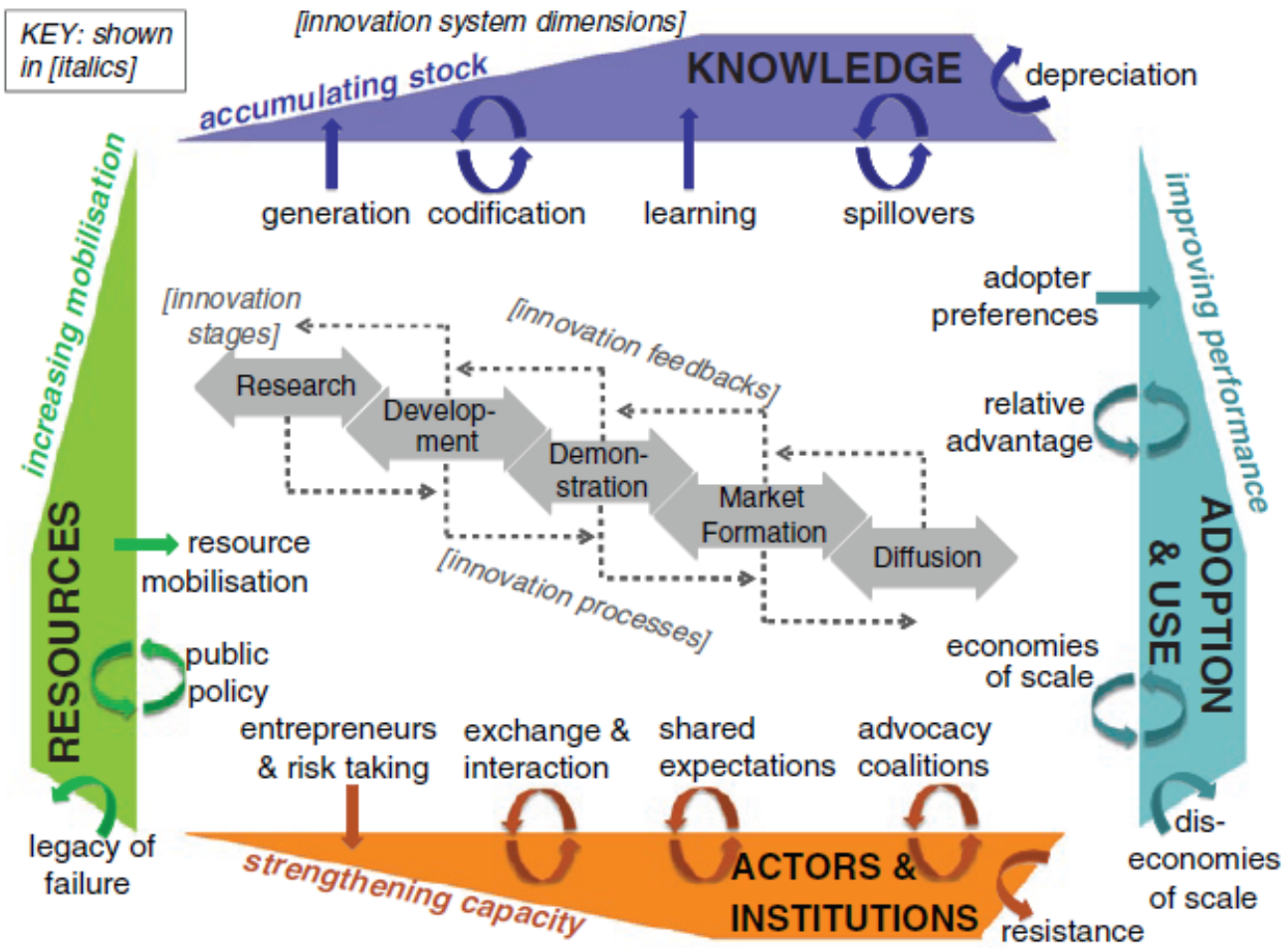

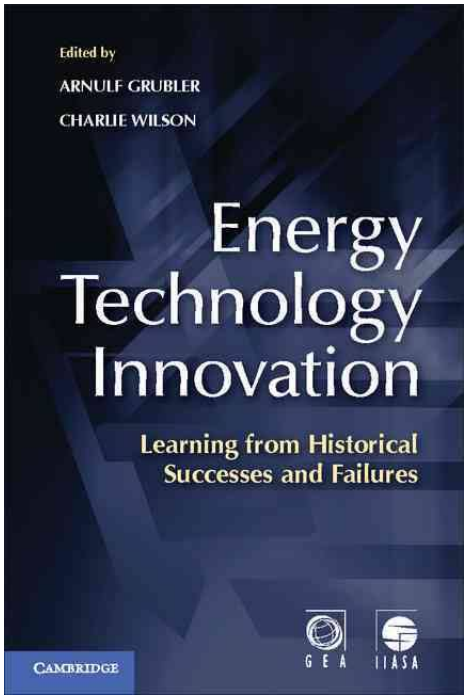

Grubler & Wilson (2014). *Energy Technology Innovation: Learning from Historical Successes & Failures.* CUP

METHODOLOGY

- **Select the most appropriate indicators from the wide variety of literature** (Borup et al., 2013; Klitkou et al., 2012; Grubler & Wilson, 2014; Cornell University, INSEAD, & WIPO, 2015; Truffer, Markard, Binz, & Jacobsson, 2012; Speirs, Pearson, & Foxon, 2008; Park, Han, Jang, Choi, & Joo, 2016; Miremadi, Saboohi, & Jacobsson, 2016; Borup, Andersen, Jacobsson, & Midttun, 2008).

1. Usefulness: indicators should be relevant and a strong predictor of the ETIS processes.

2. Availability: data should be available.

CHARACTERISE THE EU'S ENERGY INNOVATION SYSTEM

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ETIS process	Technology-specific indicators [and metrics] at the EU level	Units
Knowledge		
Generation	Public energy RD&D expenditure	€m at 2015 prices & exchange rates
	Demonstration budgets	€m at 2015 prices & exchange rates
Depreciation	Volatility in energy RD&D expenditure	index: coefficient of variation (COV)
Spillover	Knowledge spillover benefit from trade	€m: energy technology imports
Codification	Scientific publications	# articles
	Patents	# patents
Learning	Learning-by-doing	index: learning rate (LR)

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CHARACTERISE THE EU'S ENERGY INNOVATION SYSTEM

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ETIS process	Technology-specific indicators [and metrics] at the EU level	Units
Resources		
Policy Support	Innovation policy density	sum: cumulative years of all instruments
	Market-based policy density	
	Regulatory policy density	
	Innovation policy durability	average: cumulative years of all instruments
	Market-based policy durability	
	Regulatory policy durability	
Policy Diversity	Diversity of policy mix	Shannon index: three types of policy instrument
Policy Stability	Stability of policy mix	average: cumulative years of all instruments adjusted by revisions
Legacy of Failure	Decline in public interest following failures, using Google search frequency as proxy	index: exponent fitted to decline function

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CHARACTERISE THE EU'S ENERGY INNOVATION SYSTEM (PRELIMINARY)

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ETIS process	Technology-specific indicators [and metrics] at the EU level	Units
Actors & Institutions		
Capacity	Eco-innovation R&D organisations	# organisations
	Top 100 clean-tech funds	sum: cumulative funds €
Heterogeneity	Diversity in energy actors	Shannon index: type of organisation in European Energy Research Alliance
Quality Control	EU testing centres & state labs	index
Exchange & Interaction	European Energy Research Alliance activities involving different actors	numbers
Shared Expectations	Strategic goals inc. targets, roadmaps, action plans	sum: cumulative years of all goals
	Strategic goals inc. targets, roadmaps, action plans	average: cumulative years of all goals

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CHARACTERISE THE EU'S ENERGY INNOVATION SYSTEM

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ETIS process	Technology-specific indicators [and metrics] at the EU level	Units
Adoption & Use		
Relative Advantage	Market share	%: actual market as % of potential market
Market Size	Potential market size	€m: estimated as # of vehicles * €/vehicle, MW capacity * €/MW, etc.

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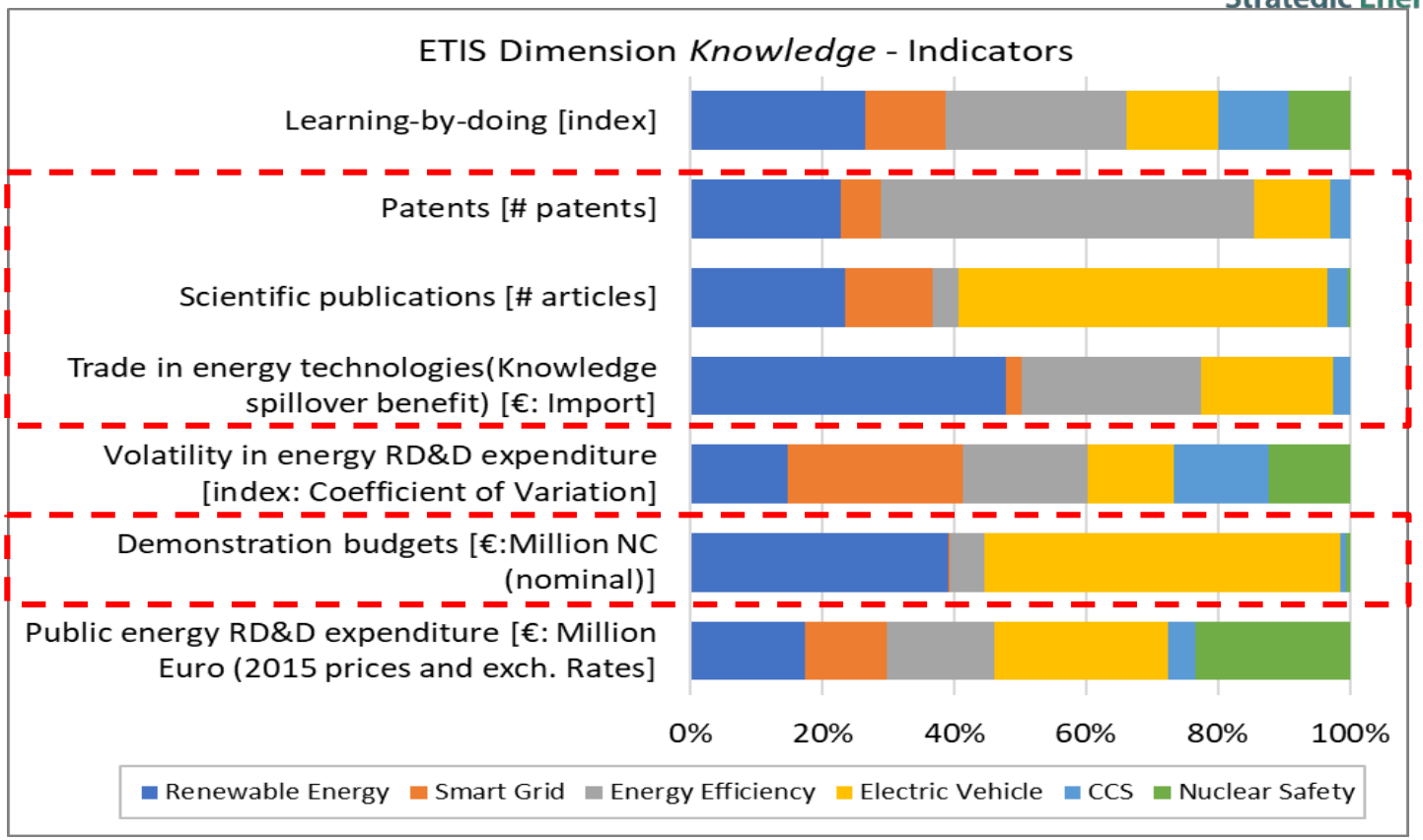
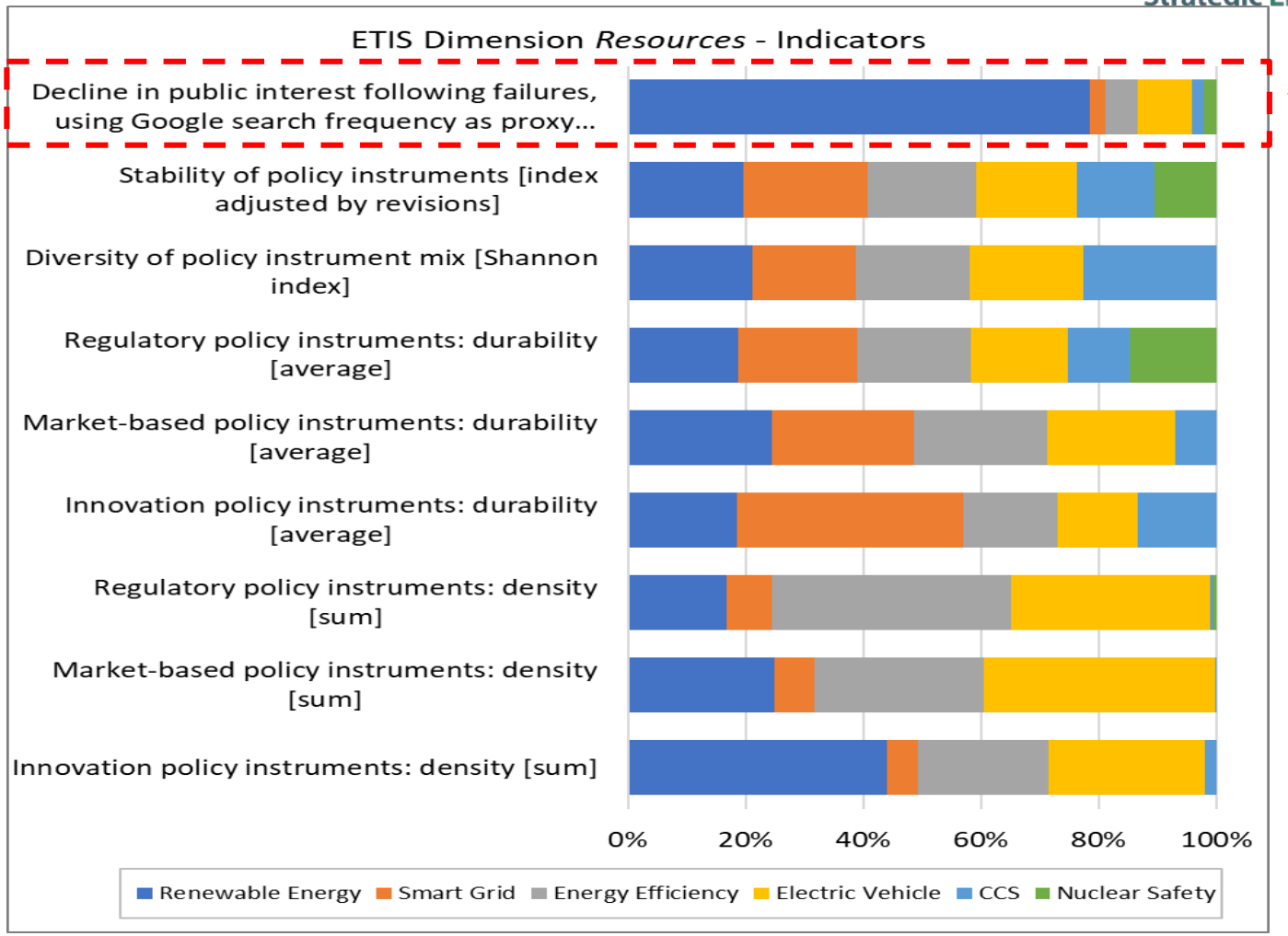
RESULTS (KNOWLEDGE)



- Strong imbalance
- Renewable Energy, Energy Efficiency, Smart Grid have the largest share

RESULTS (RESOURCES)



Solyndra bankruptcy in 2011

RESULTS (ACTORS & INSTITUTIONS) (PRELIMINARY)

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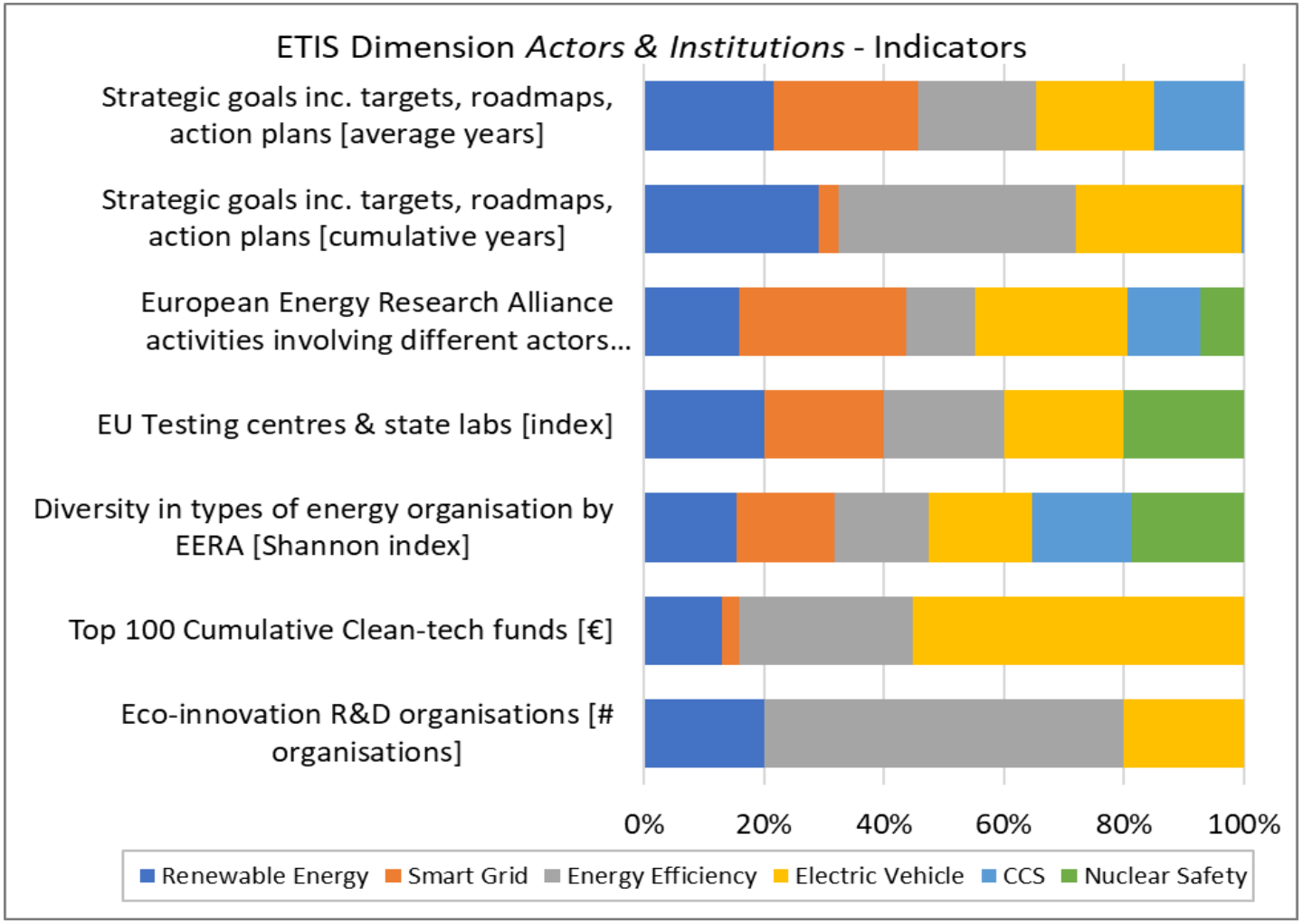

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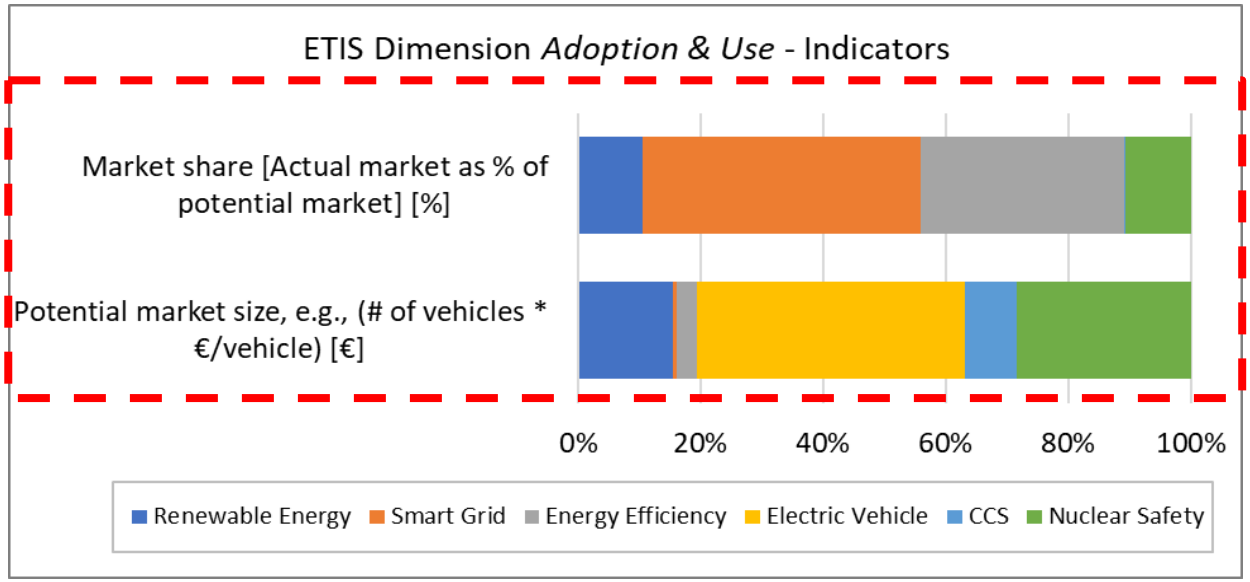
RESULTS(ADOPTION & USE)



Imbalance

- Market share (Mature technologies): smart grid, energy efficiency)
- Potential market share: electric vehicles, renewable energy, and nuclear safety(already matured field)

RESULTS (ALL ETIS DIMENSIONS)

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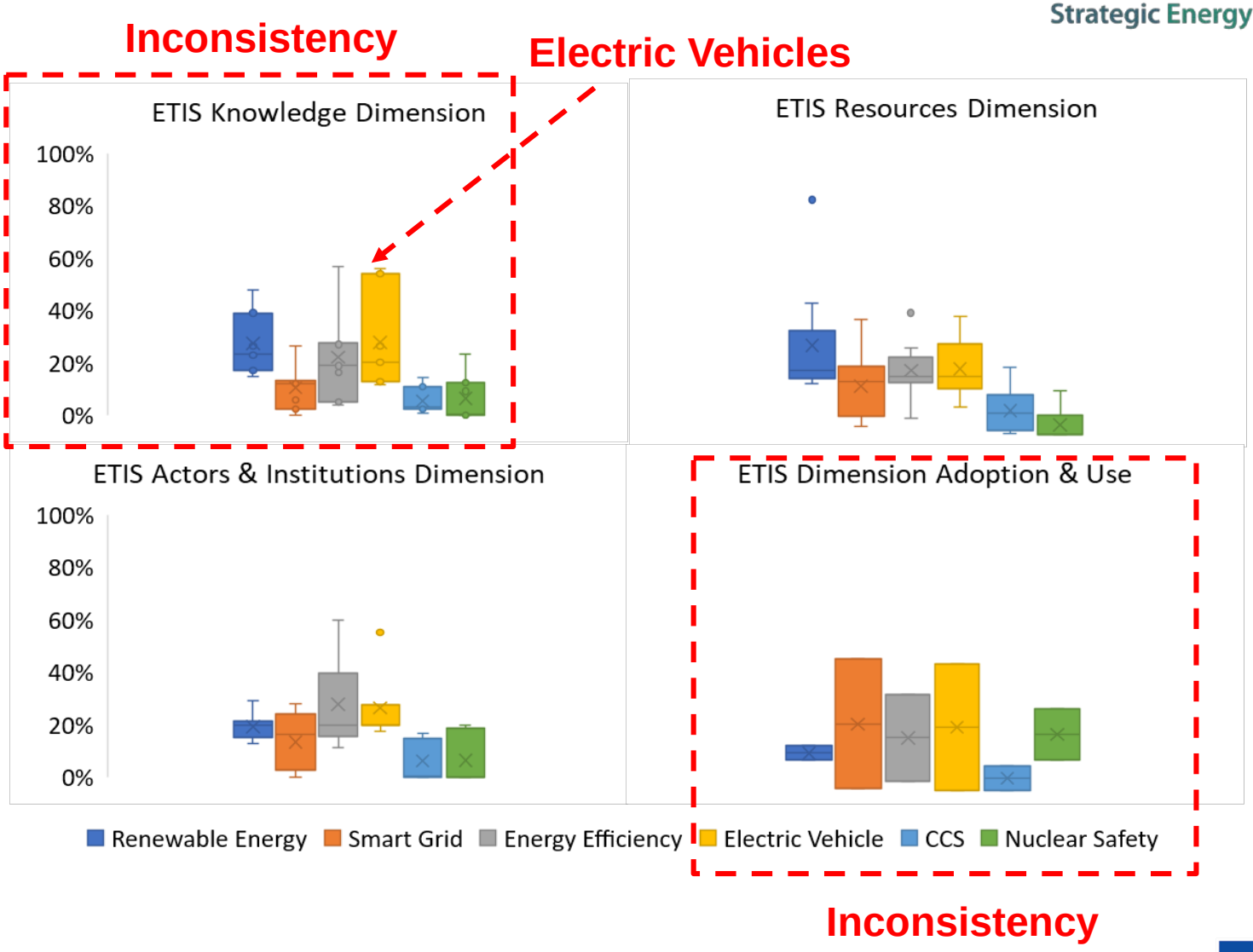

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CONCLUSIONS

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Overall Findings

- We found relatively strong progress and evidence of innovation system functioning in **renewable, electric vehicles and energy efficiency**.
- We found that **nuclear safety** and **CCS** are less emphasised.
- We also found relatively **diverse actors and organisations** in the EU energy innovation system (preliminary).
- An indicator describing early stage innovation processes would be expected to favor **electric vehicles**. However, indicators describing the late stage of innovation processes would be expected to favor **nuclear safety** and **energy efficiency**.

Future Works

- A **dynamic analysis** of the time series is the area of the future research.
- A more rigorous approach would be required to test a **causal relationship** between EU-level innovation system activity on innovation outcomes.

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Thank you!

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- **Knowledge Generation.** Public energy RD&D expenditure including demonstration budgets (International Energy Agency (IEA) RD&D database).
- **Knowledge Depreciation**

$$PV_{i,t} = \frac{1}{Coefficient\ of\ Variation_{i,t}} = \frac{1}{Policy\ Volatility}_{i,t} = \frac{\frac{1}{5}\sum_{k=0}^{4} RD\&D_{i,t-k}}{\sqrt{\frac{1}{5}\sum_{k=0}^{4}\left[RD\&D_{i,t-k} - \left(\frac{1}{5}\sum_{k=0}^{4} RD\&D_{i,t-k}\right)\right]^2}}$$

With *i* as a country, *t* as a year, and *k*=0-4 (lagged year).

- **Knowledge Spillover.** Knowledge spillover benefit was measured by the total import in energy technologies (EU trade data since 1988 by Harmonised System (HS)).
- **Knowledge Codification. Publication(Web of Science Core Collection), Patents(USPTO)**
- **Learning** (Nilsson & Nykvist, 2016; Rubin, Azevedo, Jaramillo, & Yeh, 2015; Weiss, Junginger, Patel, & Blok, 2010).

- **Policy Support. (**International Energy Agency (IEA)'s policies and measures databases).

$$Density_{p,s} = \sum_{i=1}^{n} (Endyear_i - Startyear_i)$$

With *i* as one policy instrument (*i*=1,…..,n) , *p* as types of policy instrument (p=innovation, market-based and regulatory) and *s* as SET Plan priority area (s=1,…,6).

$$Durability_{p,s} = \frac{\sum_{i=1}^{n} (Endyear_i - Startyear_i)}{n}$$

With *i* as one policy instrument (*i*=1,…..,n) , *p* as types of policy instrument (p=innovation, market-based and regulatory) and *s* as SET Plan priority area (s=1,…,6).

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- **Policy Support. (**International Energy Agency (IEA)'s policies and measures databases).

$$H_s = -\sum_i p_i \ln p_i$$

With as share of a type of policy instrument in the SET Plan priority area. The higher the value of H, the more diverse the mix of policy instruments.

- **Policy Stability. (**International Energy Agency (IEA)'s policies and measures databases).

$$Stability_s = \frac{\sum_{i=1}^{n}(Endyear_i - Startyear_i)}{n \times No.of\ Changes}$$

With *i* as one policy instrument (*i*=1,…..,n) and *s* as SET Plan priority area (s=1,…,6).

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❖ **Legacy of Failure** (Google Search Data)

$$Y_{t,s} = A \times e^{-b_s \times t}$$

$$Ln(Y_{s,t}) = -b_s \times t$$

$$Coeff_s = \frac{1}{b_s}$$

With *t* as year and *s* SET Plan priority area (s=1,…,6) .

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- **Capacity of Actors & Institutions**. (a survey of the top 100 clean-tech R&D organisations, the European Commission).
- **Heterogeneity of Actors & Institutions**

$$E_s = -\sum_s q_s \ln q_s$$

With as the share of SET Plans in the entire SET Plan.
Higher scores on E indicate a more heterogeneous mix of actors in the energy innovation system.

- **Quality Control** (European Commission's science and knowledge service)
- **Exchange & Interaction** (European Energy Research Alliance)
- **Shared Expectations** (Policy database)

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❖ Market size and share

	SET Plan	Potential Market Size (physical units)	Actual Market Size (physical units)	Market Share	Unit Cost	Potential Market Size (economic value)
[1]	Renewable Energy (RE)	1,144,025 MW	120,716 MW	10.55%	1,995,123 €/MW	2,282 € billion
[2]	Smart Grid (SG)	241,662,532 homes	110,000,000 homes	46%	422 €/home	102 € billion
[3]	Energy Efficiency (EE)			33.34%		492 € billion
	Energy Efficiency-Buildings	241,662,532 homes	16,898 homes	0.01%	3,800 €/home	918 € billion
	Energy Efficiency Appliances	535,587,700 appliances	357,076,320 appliances	66.67%	121 €/appliance	65 € billion
[4]	Electric Vehicle (EV)	198,376,808 numbers	149,500 numbers	0.08%	32,500 €/numbers	6,447 € billion
[5]	Carbon Capture & Storage (CCS)	481,916 MW	600 MW	0.12%	2,561,875 €/MW	1,235 € billion
[6]	Nuclear Safety (NS)	1,144,025 MW	121,957 MW	10.66%	3,653,490 €/MW	4,180 € billion

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