The CO2 Question: Technical Progress and the Climate Crisis

Patrick Bolton, Marcin Kacperczyk & **Moritz Wiedemann**[1]

[1]Rotterdam School of Management, Erasmus University

7th Annual GRASFI Conference at SMU
September 4, 2024

Green innovation is the silver bullet.

BlackRock. About Us Newsroom Insights Investor Relations Corporate sustainability Careers

LARRY FINK'S 2022 LETTER TO CEOS:

The next 1,000 unicorns won't be search engines or social media companies, they'll be sustainable, scalable innovators - startups that help the world decarbonize and make the energy transition affordable for all consumers

REUTERS® World Business Markets Sustainability Legal More

Environment

Bill Gates upbeat on climate innovation, even if 1.5C goal out of reach

By Katy Daigle

December 20, 2022 5:00 PM GMT · Updated a year ago

WSJ | BUSINESS

Home World U.S. Politics Economy **Business** Tech Markets Opinion Real Estate Life & Work WSJ. Magazine

Why Green Hydrogen Just Might Be the Silver Bullet Against Climate Change

By Klaus Schimmer, SAP

THE WALL STREET JOURNAL.

Tech Billionaires Bet on Fusion as Holy Grail for Business

Jeff Bezos and Bill Gates are among titans chasing almost limitless energy source

By Jennifer Hiller Follow

April 23, 2023 5:30 am ET

Green innovation is the silver bullet?

BlackRock About Us Newsroom Insights Investor Relations Corporate sustainability Careers

LARRY FINK'S 2022 LETTER TO CEOS:

The next 1,000 unicorns won't be search engines or social media companies, they'll be sustainable, scalable innovators - startups that help the world decarbonize and make the energy transition affordable for all consumers

REUTERS® World Business Markets Sustainability Legal More

Environment

Bill Gates upbeat on climate innovation, even if 1.5C goal out of reach

By Katy Daigle

December 20, 2022 5:00 PM GMT · Updated a year ago

WSJ | BUSINESS

Home World U.S. Politics Economy **Business** Tech Markets Opinion Real Estate Life & Work WSJ. Magazine

Why Green Hydrogen Just Might Be the Silver Bullet Against Climate Change

By Klaus Schimmer, SAP

THE WALL STREET JOURNAL.

Tech Billionaires Bet on Fusion as Holy Grail for Business

Jeff Bezos and Bill Gates are among titans chasing almost limitless energy source

By Jennifer Hiller Follow

April 23, 2023 5:30 am ET

Two views on the role of green innovation on emissions

Green innovation

Allows for emission reductions

- Brown firms change from carbon-intensive production to renewable production
- Brown firms improve efficiency of their fossil fuel use
- e.g. Aghion et al. (2016)

Does not allow for emission reductions

- Jevons (1865) paradox: Efficiency increases, but higher consumption dominates any efficiency gain
- Arrow: Replacement effect (1962) & Economics of learning-by-doing (1971) drive path dependency
- Displacement effect: Emissions spill over to other parts of the production network

This paper:
Global perspective on the role of green innovation in decarbonization

1. What is the impact of green innovation on future corporate emissions?

   $\Rightarrow$ More green innovation does not allow for emission reductions

2. What are possible underlying economic mechanisms?

   $\Rightarrow$ Path dependency in the production of innovation

   $\Rightarrow$ The role of the Jevons paradox

   $\Rightarrow$ Emission displacements

Outline

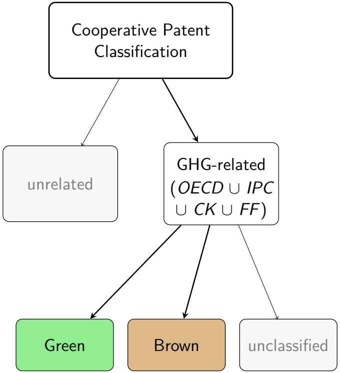
- Data and setting
- What is the impact of green innovation on future corporate emissions?
- What are possible underlying economic mechanisms?

Data: Firm-level data on carbon emissions and patenting

1. Carbon emission data from S&P Global Trucost
   - Public firm scope 1, scope 2 and scope 3 CO2 equivalent emission data
   - Coverage: 2005 to 2022
2. Patent data from Orbis Intellectual Property
   - Global patent data for public and private firms
   - Focus on patents granted by the European Patent Office (EPO) including later patent purchases
3. Financial information from Orbis, Compustat, FactSet and Worldscope

What qualifies as green innovation?

- Pool greenhouse gas related classifications from 4 sources: OECD Env-tech; IPC Green Inventory; Fossil fuels (FF) efficiency improving classes by Lanzi et al. (2011); & a self classification based on Corporate Knights Clean 200 companies (CK)
- Split greenhouse gas related classifications in 2 types:
  1. **Green**: Technologies that substitute/ enable the substitution of carbon dioxide emitting technologies for carbon dioxide-free technologies
  2. **Brown**: Technologies that improve process efficiencies of fossil fuel sources and thus reduce carbon dioxide emissions per output



Green patent example

Espacenet
Patent search

pn=EP1182710B1

Office/Language

My Espacenet | Help | Classification search | Results | Advanced search | Filters | Popup tips | Report data error | Feedback

Home > Results > EP1182710B1

EP1182710B1 SOLAR CELL BACK COVER MATERIAL, SEALING FILM AND SOLAR CELL

Available in | Patent Translate

Bibliographic data | Description | Claims | Drawings | Original document | Citations | Legal events | Patent family

Register ↗ Global Dossier ↗

Applicants	BRIDGESTONE CORP [JP] +
Inventors	IINO YASUHIRO [JP]; OTANI KAORU [JP]; TAKANO KAZUYA [JP] +
Classifications	
IPC	*B32B27/08; B32B27/28; H01L31/04; H01L31/048; H01L31/042;*
CPC	B32B17/10788 (EP,US); B32B27/08 (EP,US); B32B27/28 (EP,US); B32B27/304 (US); B32B27/306 (US); B32B27/32 (US); B32B27/322 (US); B32B27/36 (US); H01L31/049 (EP,US); B32B2323/04 (US); B32B2327/18 (US); B32B2331/04 (US); B32B2367/00 (US); B32B2457/12 (US); Y02E10/50 (EP,US); Y10T428/3154 (EP,US); Y10T428/31544 (EP,US); Y10T428/31634 (EP,US); Y10T428/31786 (EP,US);
Priorities	JP10033599A·1999-04-07; JP9906726W·1999-12-01
Application	EP99957398A·1999-12-01
Publication	EP1182710B1·2006-06-21
Published as	DE69932098T2; EP1182710A1; EP1182710A4; EP1182710B1; JP2000294813A; US6407329B1; WO0062348A1

OECD Env-tech: 2.1.3. Solar photovoltaic (PV) energy

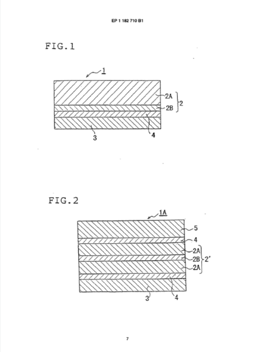
EN DE FR

SOLAR CELL BACK COVER MATERIAL, SEALING FILM AND SOLAR CELL

Abstract

Abstract not available for EP1182710B1 – abstract of corresponding document: EP1182710A1

A backside covering member (1) for a solar battery is made by integrally laminating an outer film (3) and a moistureproof film (2) with EVA adhesives (4). The moistureproof film (2) is constituted of a base film and a coating layer of an inorganic oxide deposited on a surface of said base film. A backside covering and sealing film is made by integrally laminating the aforementioned backside covering member (1) and an EVA film (6) together. A solar battery (10) is made by sealing solar cells (7) between a front side transparent protective member (8) and the aforementioned backside covering member (1) as a back side protective member. The present invention provides a backside covering member for solar battery and a backside covering and sealing film which are light and thin, are excellent in moistureproof property and durability, further have good insulation performance, and do not cause leakage of current and a durable, high-performance solar battery using the aforementioned backside covering member as a back side protective member.



Brown patent example

Espacenet
Patent search

pn=EP2521618B1

My Espacenet | Help | Classification search | Results | Advanced search | Filters | Popup tips | Report data error | Feedback

Home > Results > EP2521618B1

EP2521618B1 METHOD OF COATING A MONOLITH SUBSTRATE WITH CATALYST COMPONENT

Available in

Bibliographic data | Description | Claims | Drawings | Original document | Citations | Legal events | Patent family

Register ↗ Global Dossier ↗

Applicants JOHNSON MATTHEY PLC [GB] +

Inventors CHANDLER GUY RICHARD [GB]; FLANAGAN KEITH ANTHONY [GB]; PHILLIPS PAUL RICHARD [GB]; SCHOFIELD PAUL [GB]; SPENCER MICHAEL LEONARD WILLIAM [GB]; STRUTT HEDLEY MICHAEL [GB]; ADERHOLD DIRK [GB] +

Classifications

IPC *A44B13/00; B01J37/02; B01J37/04; B05D7/22; B28B11/04; F01N3/20;*

OECD Env-tech: 1.1.2. Emissions abatement from mobile sources (e.g. NOx, CO, HC, PM emissions from motor vehicles)

CPC A44B13/0011 (EP,KR,US); B01D53/00 (GB); B01D53/94 (GB); B01D53/9418 (US); B01J15/005 (KR,US); B01J21/08 (US); B01J27/224 (US); B01J29/763 (US); B01J3/03 (KR); B01J35/04 (US); B01J37/02 (KR); B01J37/0215 (GB); B01J37/0246 (US); B05C9/02 (GB,KR); B05C9/04 (KR); B05C9/045 (KR); B05D1/00 (GB); B05D1/002 (GB); B05D5/00 (GB); B05D7/22 (GB,KR); B05D7/24 (GB); F01N3/035 (GB); F01N3/08 (KR); F01N3/105 (GB); F01N3/20 (GB,KR); F01N3/2066 (GB); B01D2255/91 (US); B01D2255/9155 (US); B05C9/02 (US); B05C9/04 (US); B05C9/045 (US);

Priorities GB201000019A·2010-01-04; GB2011050005W·2011-01-04

Application EP11702492A·2011-01-04

Publication EP2521618B1·2013-08-28

Published as AR081146A1; AU2011203392A1; BR112012016574A2; CN102781586A; CN102781586B; DE102011002449A1; DK2521618T3; EP2521618A1; EP2521618B1;EP2521618B8; EP2659976A1; EP2659976B1; EP2659976B8; EP2889083A1; GB2477602A; GB2477602A8; GB2477602B; GB2477602B8; GB2487847A; GB2487847A8; GB2487847B; GB2487847B8; HK1178482A1; JP2013516307A; JP2015062896A; JP5646649B2; JP5883909B2; KR101789665B1; KR20120105554A; MX2012007828A; MY159963A; PL2521618T3; RU2012133433A; RU2014151995A; RU2014151995A3; RU2541575C2; SG182338A1; US2011268624A1; US2014186232A1; US2016325272A1; US8703236B2; US9415365B2; WO2011080525A1; ZA201204800B

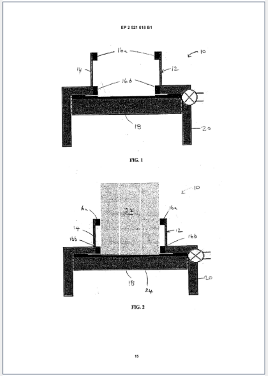
EN FR DE

METHOD OF COATING A MONOLITH SUBSTRATE WITH CATALYST COMPONENT

Abstract

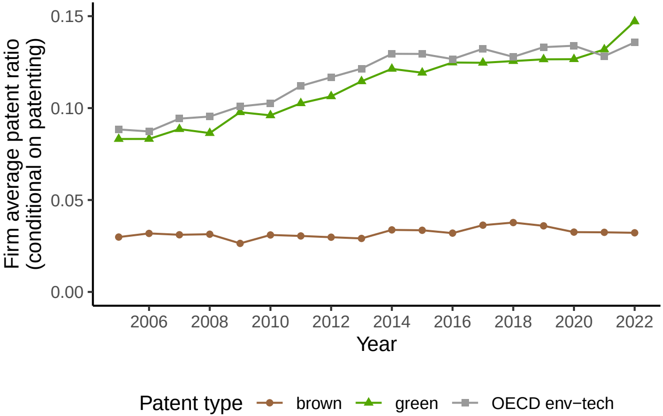
Abstract not available for EP2521618B1 – abstract of corresponding document: WO2011080525A1

A method of coating a honeycomb monolith substrate comprising a plurality of channels with a liquid comprising a catalyst component comprises the steps of: (i) holding a honeycomb monolith substrate substantially vertically; (ii) introducing a pre-determined volume of the liquid into the substrate via open ends of the channels at a lower end of the substrate; (iii) sealingly retaining the introduced liquid within the substrate; (iv) inverting the substrate containing the retained liquid; and (v) applying a vacuum to open ends of the channels of the substrate at the inverted, lower end of the substrate to draw the liquid along the channels of the substrate.



Patent ratio, as innovation measure, to focus on relative attention

$$\text{GREENRATIO}_{f,t} = \frac{\text{Green patent count}_{f,t}}{\text{Any patent count}_{f,t}}; \qquad \text{BROWNRATIO}_{f,t} = \frac{\text{Brown patent count}_{f,t}}{\text{Any patent count}_{f,t}}$$



Outline

Data and setting

What is the impact of green innovation on future corporate emissions?

What are possible underlying economic mechanisms?

Does green/ brown innovation allow for emission reductions?

$$y_{f,t:t+2} = \beta_0 + \beta_1 \text{Patent Ratio}_{f,t-3:t-1} + \Omega Controls_{f,t-3:t-1} + \Gamma_f + \Gamma_{j\times t} + \varepsilon_{f,t}$$

	(1) $LOGS1TOT_{t:t+2}$	(2) $LOGS2TOT_{t:t+2}$	(3) $LOGS3UPTOT_{t:t+2}$	(3) $LOGS3DOWNTOT_{t:t+2}$
Panel A: Green innovation				
$GREENRATIO_{f,t-3:t-1}$	0.004	0.022	0.013	−0.031
	(0.035)	(0.036)	(0.017)	(0.082)
R2 Full Model	0.967	0.967	0.985	0.953
R2 Reduced Model	0.967	0.967	0.985	0.953
Partial R2 (x10e-5)	0.00864	0.364	0.281	0.139
Observations	39159	39159	39159	21521
Panel B: Brown innovation				
$BROWNRATIO_{f,t-3:t-1}$	0.109*	−0.016	0.025	0.234
	(0.059)	(0.065)	(0.029)	(0.168)
R2 Full Model	0.967	0.967	0.985	0.953
R2 Reduced Model	0.967	0.967	0.985	0.953
Partial R2 (x10e-5)	1.947	0.0627	0.311	2.078
Observations	39159	39159	39159	21521
Controls	yes	yes	yes	yes
Industry-Year F.E.	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes

Controls include: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, LOGASSETS, LOGAGE, BETA, VOLAT, RET, and MSCI. Standard errors are double clustered at firm and year dimension.

How large is the explanatory power of green/brown innovation?

$$y_{f,t:t+2} = \beta_0 + \beta_1 \text{Patent Ratio}_{f,t-3:t-1} + \Omega Controls_{f,t-3:t-1} + \Gamma_f + \Gamma_{j\times t} + \varepsilon_{f,t}$$

	(1) $LOGS1TOT_{t:t+2}$	(2) $LOGS2TOT_{t:t+2}$	(3) $LOGS3UPTOT_{t:t+2}$	(3) $LOGS3DOWNTOT_{t:t+2}$
Panel A: Green innovation				
$GREENRATIO_{f,t-3:t-1}$	0.004	0.022	0.013	−0.031
	(0.035)	(0.036)	(0.017)	(0.082)
R2 Full Model	0.967	0.967	0.985	0.953
R2 Reduced Model	0.967	0.967	0.985	0.953
Partial R2 (x10e-5)	0.00864	0.364	0.281	0.139
Observations	39159	39159	39159	21521
Panel B: Brown innovation				
$BROWNRATIO_{f,t-3:t-1}$	0.109*	−0.016	0.025	0.234
	(0.059)	(0.065)	(0.029)	(0.168)
R2 Full Model	0.967	0.967	0.985	0.953
R2 Reduced Model	0.967	0.967	0.985	0.953
Partial R2 (x10e-5)	1.947	0.0627	0.311	2.078
Observations	39159	39159	39159	21521
Controls	yes	yes	yes	yes
Industry-Year F.E.	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes

Controls include: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, LOGASSETS, LOGAGE, BETA, VOLAT, RET, and MSCI. Standard errors are double clustered at firm and year dimension.

Outline

Data and setting

What is the impact of green innovation on future corporate emissions?

What are possible underlying economic mechanisms?

[1] Increase in sales and improvements in emission intensity in line with the Jevons Paradox

$$y_{f,t:t+2} = \beta_0 + \beta_1 \text{BROWNRATIO}_{f,t-3:t-1} + \Omega Controls_{f,t-3:t-1} + \Gamma_f + \Gamma_{j \times t} + \varepsilon_{f,t}$$

	(1) $S1INT_{t:t+2}$	(2) $S2INT_{t:t+2}$	(3) $S3UPINT_{t:t+2}$	(4) $S3DOWNINT_{t:t+2}$	(5) $LOGSALES_{t:t+2}$	(6) $LOGCAPEX_{t:t+2}$
$BROWNRATIO_{f,t-3:t-1}$	-0.073	-0.059^{**}	-0.142^{***}	-0.155	0.067^{***}	0.138^{**}
	(0.245)	(0.026)	(0.046)	(1.232)	(0.021)	(0.057)
Observations	39159	39159	39159	21521	39159	39068
R2	0.940	0.865	0.938	0.903	0.984	0.954
Controls	yes	yes	yes	yes	yes	yes
Industry-Year F.E.	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes

Controls include: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, LOGASSETS, LOGAGE, BETA, VOLAT, RET, and MSCI. Standard errors are double clustered at firm and year dimension.

[2] Little impact of green innovation

$$y_{f,t:t+2} = \beta_0 + \beta_1 \text{GREENRATIO}_{f,t-3:t-1} + \Omega Controls_{f,t-3:t-1} + \Gamma_f + \Gamma_{j\times t} + \varepsilon_{f,t}$$

	(1) $S1INT_{t:t+2}$	(2) $S2INT_{t:t+2}$	(3) $S3UPINT_{t:t+2}$	(4) $S3DOWNINT_{t:t+2}$	(5) $LOGSALES_{t:t+2}$	(6) $LOGCAPEX_{t:t+2}$
$GREENRATIO_{f,t-3:t-1}$	0.210	0.017	0.001	0.324	0.002	-0.016
	(0.144)	(0.018)	(0.037)	(0.532)	(0.015)	(0.029)
Observations	39159	39159	39159	21521	39159	39068
R2	0.940	0.865	0.938	0.903	0.984	0.954
Controls	yes	yes	yes	yes	yes	yes
Industry-Year F.E.	yes	yes	yes	yes	yes	yes
Firm F.E.	yes	yes	yes	yes	yes	yes

Controls include: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, LOGASSETS, LOGAGE, BETA, VOLAT, RET, and MSCI. Standard errors are double clustered at firm and year dimension.

$\Rightarrow$ Possibly due to low ex-ante emissions?

[2] Path dependency in the production of innovation

Consistent with the Arrow replacement effect (Arrow 1962) & learning-by-doing (Arrow 1971)

$$PATENTRATIO_{f,t} = \beta_0 + \beta_1 EMISSION_{f,t-1} + \beta_2 AGE_{f,t-1} + \beta_3 STOCK_{f,t-1} + \Omega Controls_{f,t-1} + \Gamma_c + \Gamma_{i*t} + \varepsilon_{f,t}$$

	(1)	(2)	(3)	(4)	(5)	(6)
		$GREENRATIO_t$			$BROWNRATIO_t$	
$LOGS123UPTOT_{f,t-1}$	0.055**	−0.054***	−0.003			
	(0.025)	(0.018)	(0.024)			
$LOGAGE_{f,t-1}$	−0.186***	−0.150***	−0.078			
	(0.036)	(0.031)	(0.118)			
$PATSTOCKGREEN(/100)_{f,t-1}$	0.053***	0.058***	−0.001			
	(0.011)	(0.011)	(0.005)			
$PATSTOCKBROWN(/100)_{f,t-1}$	−0.034***	−0.056***	0.009			
	(0.013)	(0.013)	(0.011)			
Country F.E.	yes	yes	yes			
Year F.E.	yes	no	no			
Industry X Year F.E.	no	yes	yes			
Firm F.E.	no	no	yes			
Observations	32366	31750	23643			
Pseudo R2	0.0364	0.109	0.221			

Estimated with Poisson pseudo-maximum likelihood. Other controls include: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, RET, and MSCI. Standard errors are double clustered at firm and year dimension.

[2] Path dependency in the production of innovation

Consistent with the Arrow replacement effect (Arrow 1962) & learning-by-doing (Arrow 1971)

$$PATENTRATIO_{f,t} = \beta_0 + \beta_1 EMISSION_{f,t-1} + \beta_2 AGE_{f,t-1} + \beta_3 STOCK_{f,t-1} + \Omega Controls_{f,t-1} + \Gamma_c + \Gamma_{i*t} + \varepsilon_{f,t}$$

	(1)	(2)	(3)	(4)	(5)	(6)
	$GREENRATIO_t$			$BROWNRATIO_t$		
$LOGS123UPTOT_{f,t-1}$	0.055**	−0.054***	−0.003	0.277***	0.003	−0.007
	(0.025)	(0.018)	(0.024)	(0.044)	(0.043)	(0.087)
$LOGAGE_{f,t-1}$	−0.186***	−0.150***	−0.078	0.122*	0.083	−0.040
	(0.036)	(0.031)	(0.118)	(0.066)	(0.061)	(0.218)
$PATSTOCKGREEN(/100)_{f,t-1}$	0.053***	0.058***	−0.001	−0.114***	−0.104***	−0.018
	(0.011)	(0.011)	(0.005)	(0.027)	(0.034)	(0.011)
$PATSTOCKBROWN(/100)_{f,t-1}$	−0.034***	−0.056***	0.009	0.147***	0.123***	0.003
	(0.013)	(0.013)	(0.011)	(0.026)	(0.032)	(0.011)
Country F.E.	yes	yes	yes	yes	yes	yes
Year F.E.	yes	no	no	yes	no	no
Industry X Year F.E.	no	yes	yes	no	yes	yes
Firm F.E.	no	no	yes	no	no	yes
Observations	32366	31750	23643	32255	27933	13723
Pseudo R2	0.0364	0.109	0.221	0.0711	0.168	0.273

Estimated with Poisson pseudo-maximum likelihood. Other controls include: LOGSIZE, LOGPPE, LEVERAGE, ROE, M/B, INVEST/A, BETA, VOLAT, RET, and MSCI. Standard errors are double clustered at firm and year dimension.

[3] Firms with higher green patent ratios tend to lose market share

A form of emission displacement

$$MARKETSHARE_{f,t:t+2} = \beta_0 + \beta_1 \text{Patent Ratio}_{f,t-3:t-1} + \Omega Controls_{f,t-3:t-1} + \Gamma_f + \Gamma_{j \times t} + \varepsilon_{f,t}$$

	(1)	(2)
	$MARKETSHARE_t$	
$GREENRATIO_{f,t-3:t-1}$	-0.018^{**}	
	(0.008)	
$BROWNRATIO_{f,t-3:t-1}$		0.003
		(0.008)
Observations	115895	115895
R2	0.965	0.965
Controls	yes	yes
Firm F.E.	yes	yes
Industry × Year F.E.	yes	yes

Other controls include: LOGASSETS, LOGPPE, LEVERAGE, ROE, INVEST/A, LOGAGE, and PUBLIC. Standard errors are double clustered at firm and year dimension.

Conclusion

- More green innovation does not translate into reductions in emissions
  - ⇒ Consistent with Jevons paradox
  - ⇒ Consistent with displacement effect
- Companies do not switch their innovation profile
  - ⇒ Path-dependency consistent with Arrow replacement effect and learning-by doing
  - ⇒ Path dependency extends beyond firm operations to the production network
- Policy implications:
  - ⇒ Decarbonization may require coordination of efforts across companies and sectors
  - ⇒ Public sector green industrial policy can help overcome ecosystem replacement effects