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Digital and Green Transitions: Opportunities and Challenges for Europe and China

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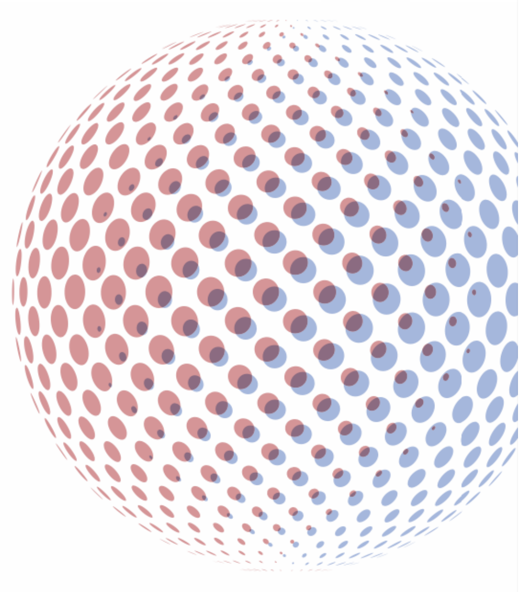
Digital Power China

A European research consortium



REVERSE DEPENDENCY:

MAKING EUROPE'S DIGITAL TECHNOLOGICAL STRENGTHS INDISPENSABLE TO CHINA

MAY 2024 | EDITOR: TIM RÜHLIG

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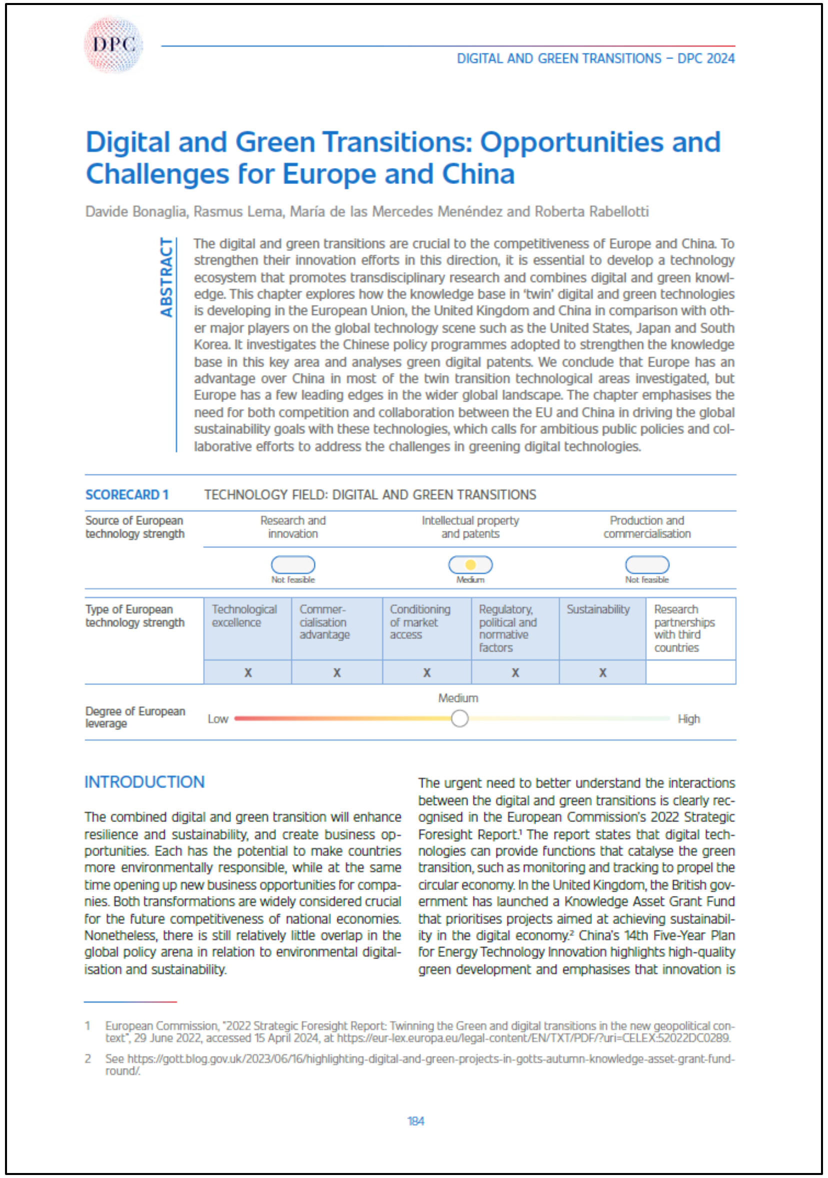

DIGITAL AND GREEN TRANSITIONS – DPC 2024

Digital and Green Transitions: Opportunities and Challenges for Europe and China

Davide Bonaglia, Rasmus Lema, María de las Mercedes Menéndez and Roberta Rabellotti

ABSTRACT

The digital and green transitions are crucial to the competitiveness of Europe and China. To strengthen their innovation efforts in this direction, it is essential to develop a technology ecosystem that promotes transdisciplinary research and combines digital and green knowledge. This chapter explores how the knowledge base in 'twin' digital and green technologies is developing in the European Union, the United Kingdom and China in comparison with other major players on the global technology scene such as the United States, Japan and South Korea. It investigates the Chinese policy programmes adopted to strengthen the knowledge base in this key area and analyses green digital patents. We conclude that Europe has an advantage over China in most of the twin transition technological areas investigated, but Europe has a few leading edges in the wider global landscape. The chapter emphasises the need for both competition and collaboration between the EU and China in driving the global sustainability goals with these technologies, which calls for ambitious public policies and collaborative efforts to address the challenges in greening digital technologies.

SCORECARD 1 TECHNOLOGY FIELD: DIGITAL AND GREEN TRANSITIONS

Source of European technology strength	Research and innovation	Intellectual property and patents	Production and commercialisation
	Not feasible	Medium	Not feasible

Type of European technology strength	Technological excellence	Commer-cialisation advantage	Conditioning of market access	Regulatory, political and normative factors	Sustainability	Research partnerships with third countries
	X	X	X	X	X	

Degree of European leverage: Low — Medium — High

INTRODUCTION

The combined digital and green transition will enhance resilience and sustainability, and create business opportunities. Each has the potential to make countries more environmentally responsible, while at the same time opening up new business opportunities for companies. Both transformations are widely considered crucial for the future competitiveness of national economies. Nonetheless, there is still relatively little overlap in the global policy arena in relation to environmental digitalisation and sustainability.

The urgent need to better understand the interactions between the digital and green transitions is clearly recognised in the European Commission's 2022 Strategic Foresight Report.[1] The report states that digital technologies can provide functions that catalyse the green transition, such as monitoring and tracking to propel the circular economy. In the United Kingdom, the British government has launched a Knowledge Asset Grant Fund that prioritises projects aimed at achieving sustainability in the digital economy.[2] China's 14th Five-Year Plan for Energy Technology Innovation highlights high-quality green development and emphasises that innovation is

1 European Commission, "2022 Strategic Foresight Report: Twinning the Green and digital transitions in the new geopolitical context", 29 June 2022, accessed 15 April 2024, at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0289.

2 See https://gott.blog.gov.uk/2023/06/16/highlighting-digital-and-green-projects-in-gotts-autumn-knowledge-asset-grant-fund-round/.

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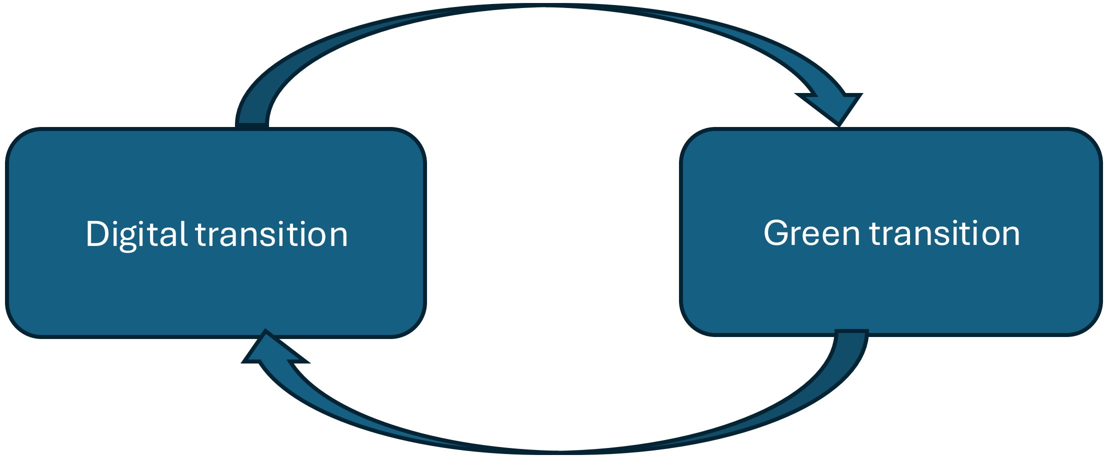
Bonaglia, D., Lema, R., Menéndez de Medina, M., & Rabellotti, R. (2024). Digital and Green Transitions: Opportunities and Challenges for Europe and China. In T. Rühlig (Ed.), Reverse Dependency: Making Europe's Digital - Technological Strengths Indispensable to China (pp. 184-207). Digital Power China.

The twin transition

- The Twin Transition describes the simultaneous shift toward a sustainable, low-carbon economy (green transition) and the digitalization of industries and services (digital transition).

- It emphasizes how digital innovation can support environmental sustainability, improving resource efficiency, reducing emissions, and fostering economic growth.

Digital technologies
- greener, e.g., by reducing energy consumption
- support of the green transition in other sectors



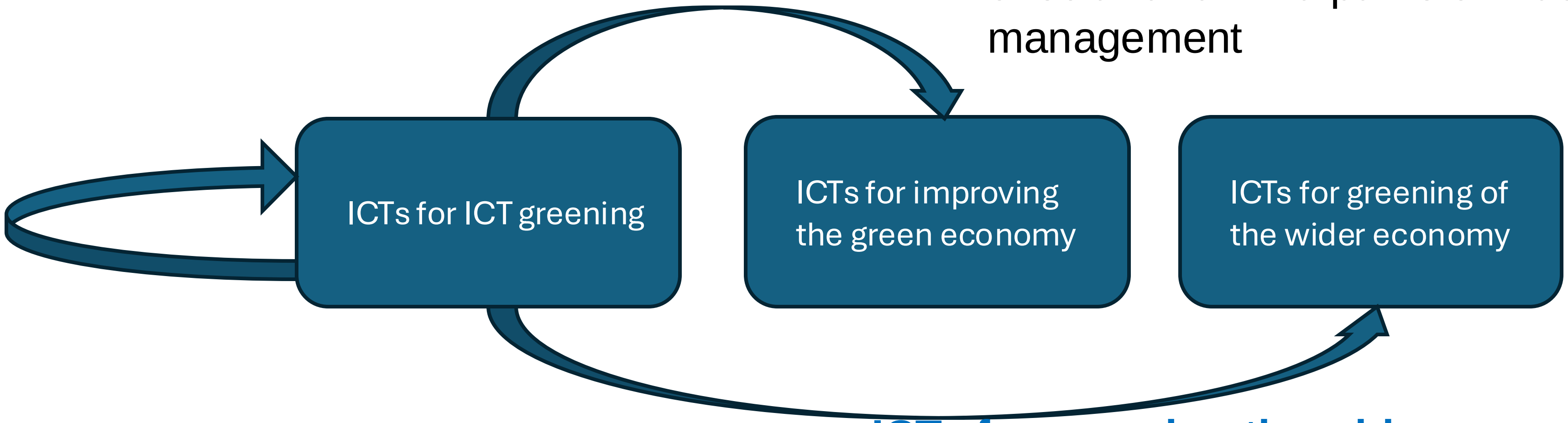
Green technologies
- support the digital economy (e.g., green electricity for data centers)
- Green priorities and institutional arrangements shape the direction of digital innovation

What are the twin transition technologies (TTTs)?

- Twin transition technologies (TTTs) emerge when digital technologies meet sustainability objectives.
- We propose a classification of digital innovations developed (or applied) for direct or indirect environmental gains.

ICTs for improving the green economy
e.g., improving the performance of solar and wind parks or waste management

ICTs for ICT greening
e.g., reducing energy consumption in data processing or reducing e-waste



ICTs for greening the wider economy
e.g., improving the environmental performance of manufacturing production

Methodology

Database: 66.648 patent applications filed at USPTO, EPO and JPO from 2000 to 2022

Green technologies: Y02/Y04S technological codes for climate change mitigation technologies

Digital technologies: based on WIPO identification of General Purpose Technologies (GPTs) including artificial intelligence (AI), machine learning (ML), autonomous systems, big data, cloud computing, internet-of-things (IoT) and robotics.

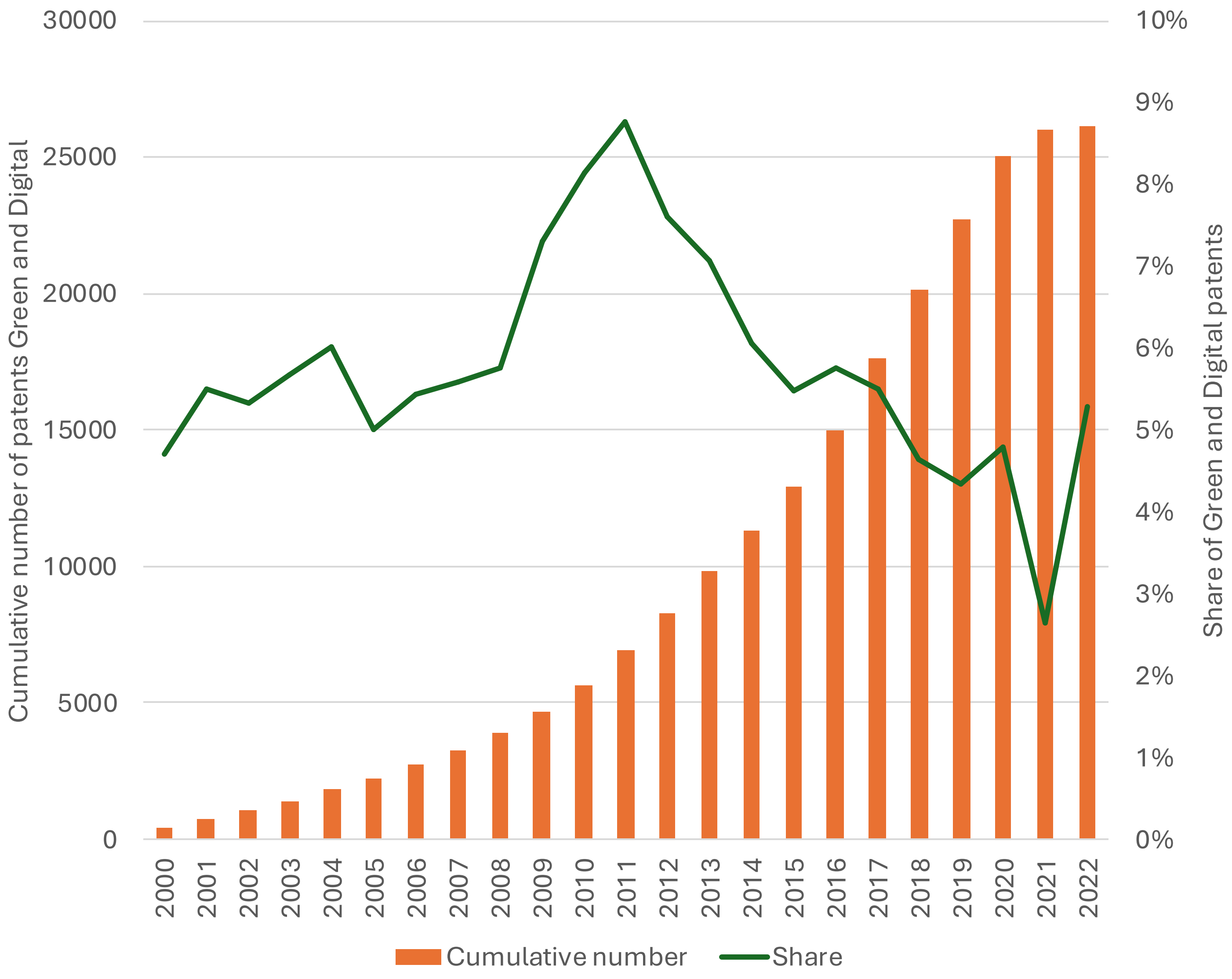
Green technologies and TTT classes

TABLE 1: Climate change mitigation technologies and smart grids

CPC	DESCRIPTION	KEYWORDS
Y02	**Technologies or Applications for Mitigation or adaptation against climate change**	
Y02A	Technologies for adaptation to climate change	Adaptation
Y02B	Climate change mitigation technologies related to buildings	Buildings
Y02C	Capture, storage, sequestration, or disposal of greenhouse gasses	Greenhouse gas capture and storage
Y02D	Climate change mitigation technologies in information and communication technologies	Green-ICT
Y02E	Reduction of greenhouse gas emissions related to energy generation, transmission, or distribution	Energy
Y02P	Climate change mitigation technologies in the production or processing of goods	Production
Y02T	Climate change mitigation technologies related to transportation	Transports
Y02W	Climate change mitigation technologies related to wastewater treatment or waste management	Waste
Y04	**Information or communication technologies with an impact on other technology areas**	
Y04S	Systems integrating technologies related to power network operation, communication, or information technologies for improving electrical power generation, transmission, distribution, management or usage, i.e. smart grids	Smart Grids

ICTs for ICT greening (TTT1)	• Green-ICT (Y02D)
ICTs for improving the green economy (TTT2)	• Adaptation (Y02A) • Greenhouse gas capture and storage (Y02C) • Energy (Y02E) • Waste (Y02W) • Smart grids (Y04S)
ICTs for greening the wider economy (TTT3)	• Buildings (Y02B) • Production (Y02P) • Transports (Y02T)

Figure 1. Green Digital cumulative evolution and share



Green digital patents are less than 10% of total digital patents

Source: WIPO (only includes USPTO patents)

- **Building, Production and Transport (TT3)** are the most relevant class in green-digital technologies;
- Most of the combinations include **TT2** and **TT3**;

Figure 3. Digital green technologies by TTT categories

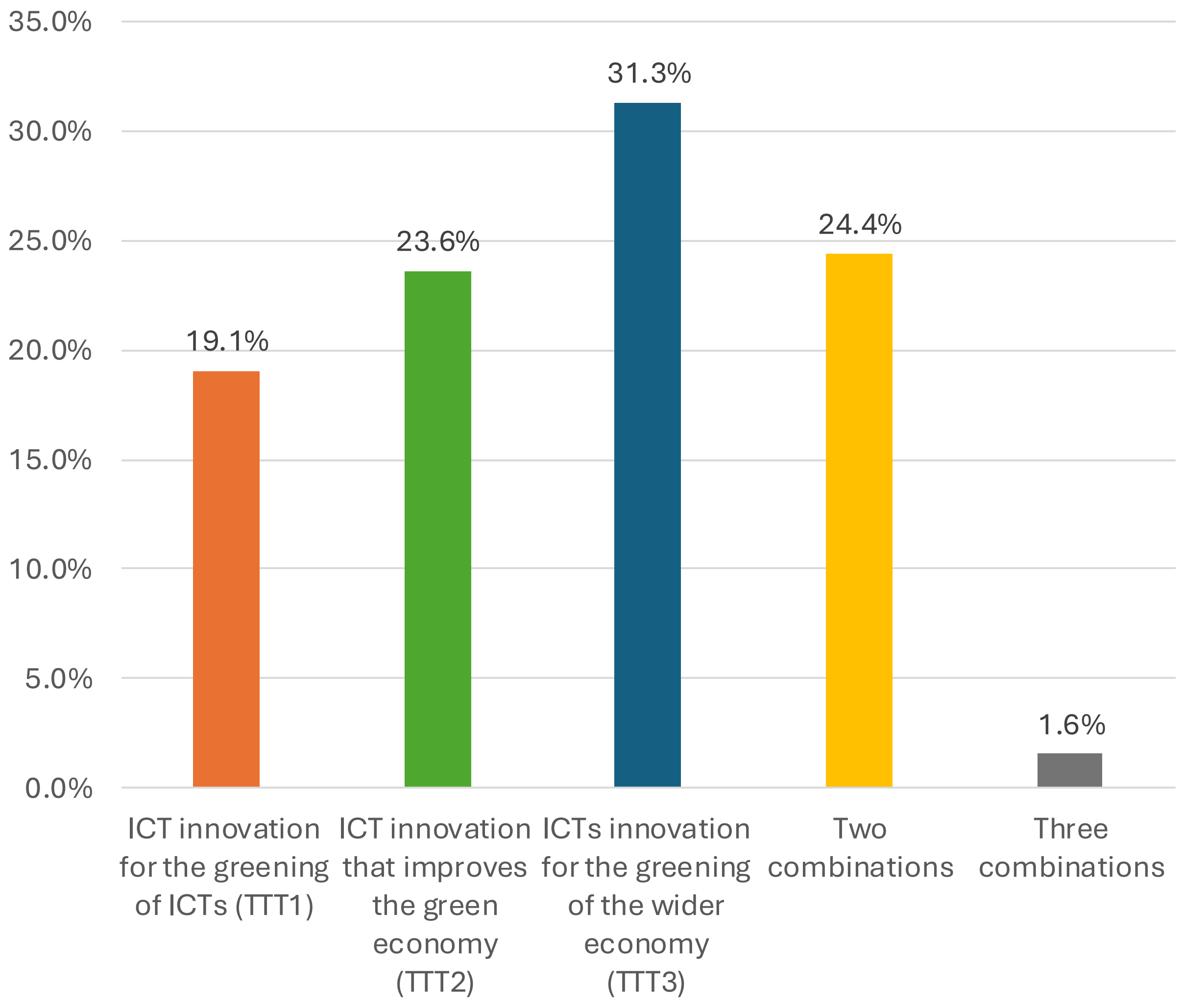
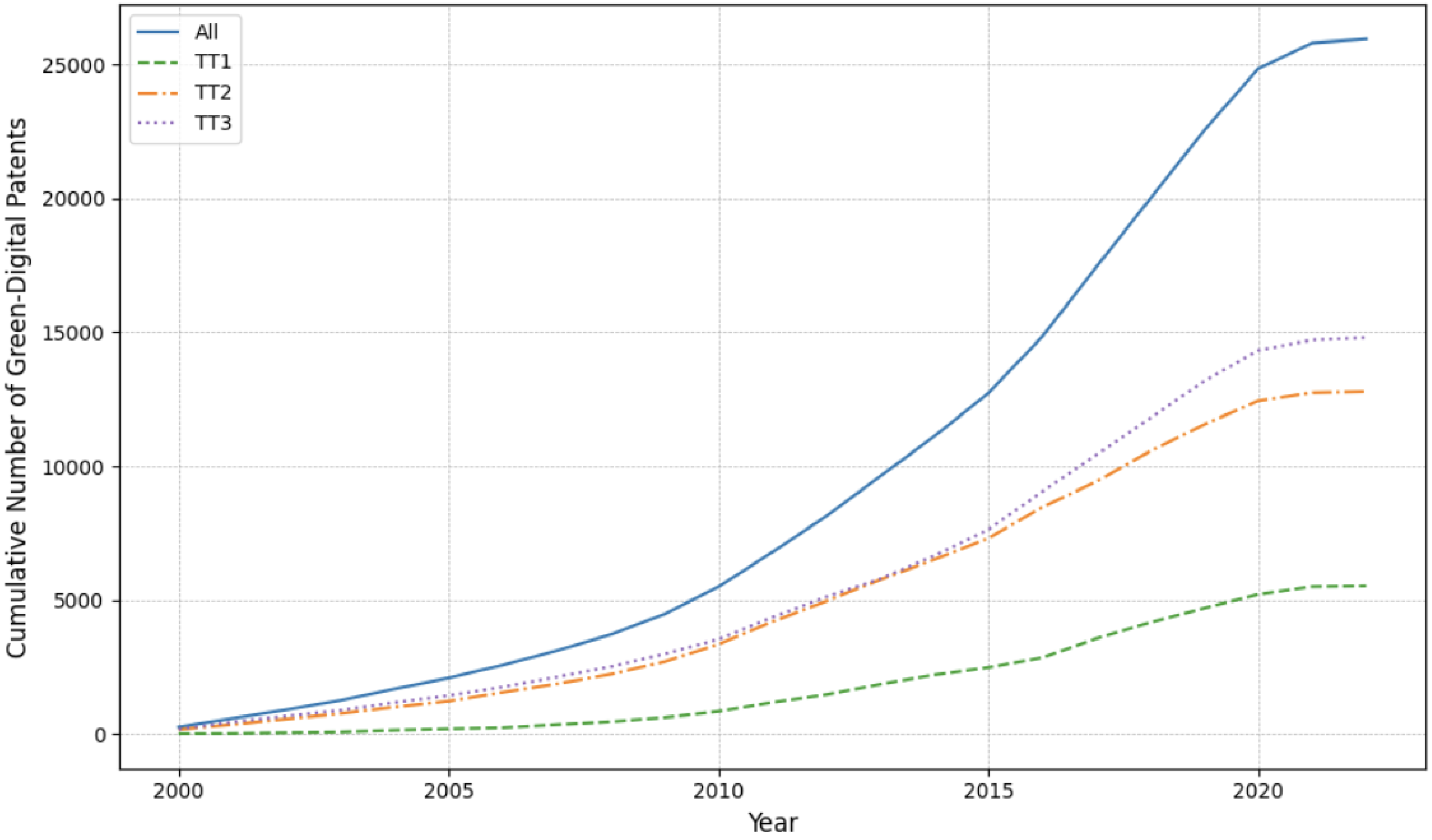
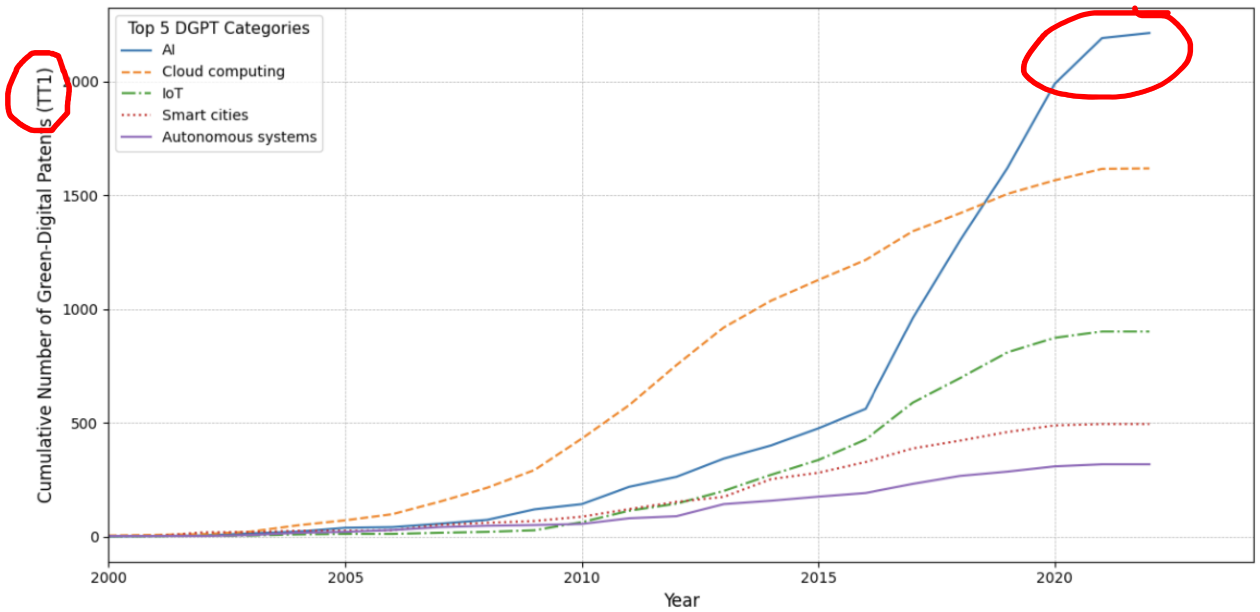
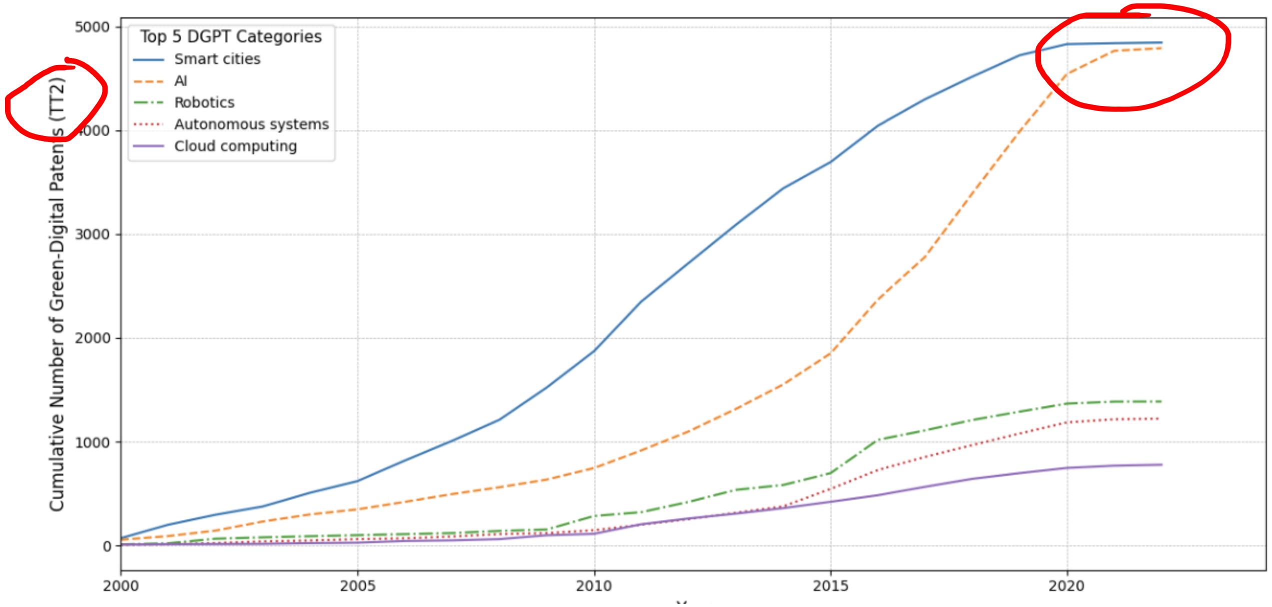


Figure 2. Evolution of TTT by categories




Top 5 DGPT Categories
AI
Cloud computing
IoT
Smart cities
Autonomous systems
Cumulative Number of Green-Digital Patents (TT1)
Year
0
500
1000
1500
2000
2005
2010
2015
2020


Top 5 DGPT Categories
Smart cities
AI
Robotics
Autonomous systems
Cloud computing
Cumulative Number of Green-Digital Patents (TT2)
0
1000
2000
3000
4000
5000
2000
2005
2010
2015
2020

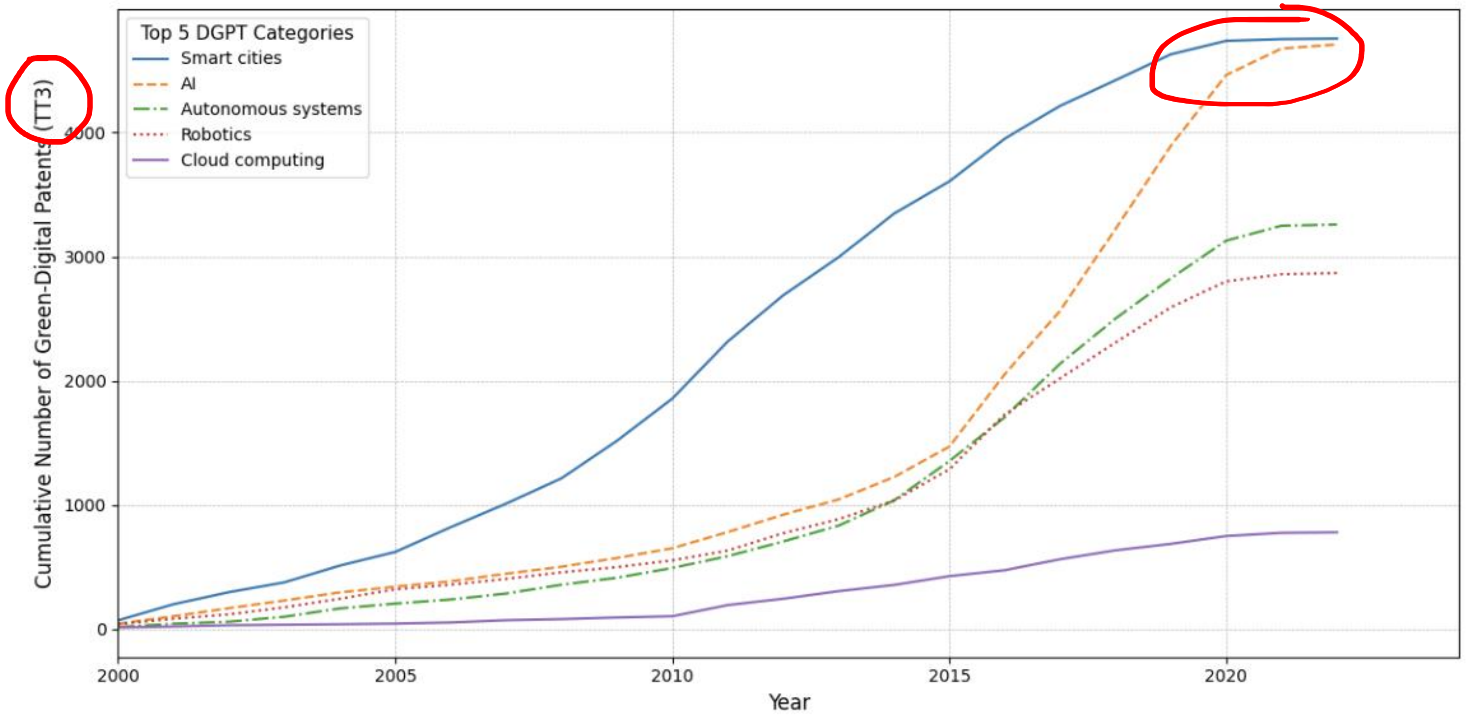
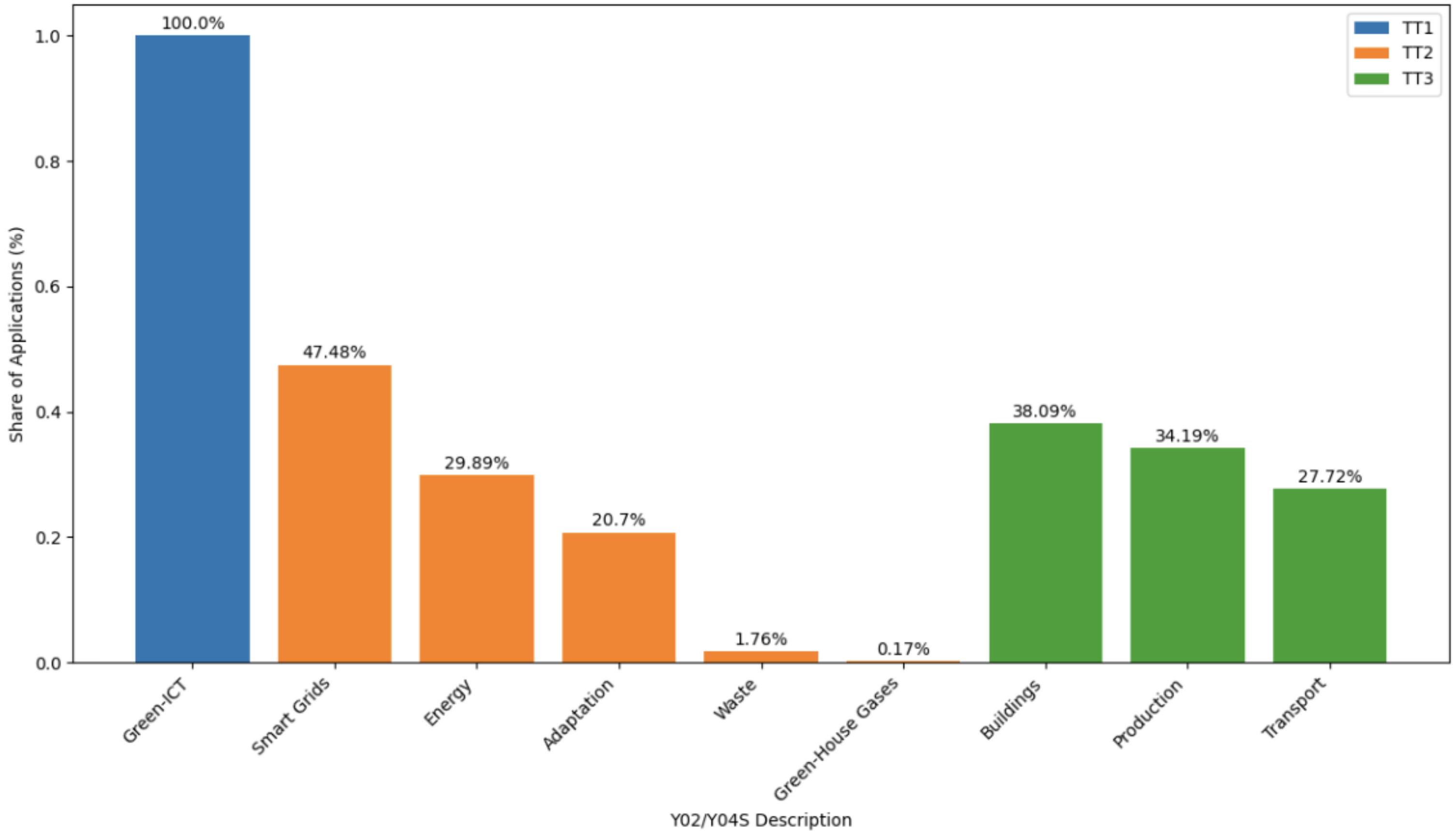

Top 5 DGPT Categories
Smart cities
AI
Autonomous systems
Robotics
Cloud computing
Cumulative Number of Green-Digital Patents (TT3)
Year
0
1000
2000
3000
4000
2000
2005
2010
2015
2020

Figure 4. TTT by Y02/Y04 categories



Digital green patent applications by countries, 2000-2022

Country	Number of patents	Share	Cumulative share
United States	14701	57,37%	57,37%
Japan	2470	9,64%	67,01%
China	1842	7,19%	74,20%
Korea	1456	5,68%	79,88%
Germany	886	3,46%	83,33%
Canada	539	2,10%	85,44%
Taiwan	506	1,98%	87,41%
Great Britain	392	1,53%	88,94%
France	339	1,32%	90,27%
Switzerland	328	1,28%	91,55%
Israel	323	1,26%	92,81%
Sweden	234	0,91%	93,72%
Netherlands	160	0,63%	94,35%
Denmark	145	0,57%	94,91%
India	143	0,56%	95,47%
Rest of the world	1161	4,53%	100,00%
Sum	**25625**		

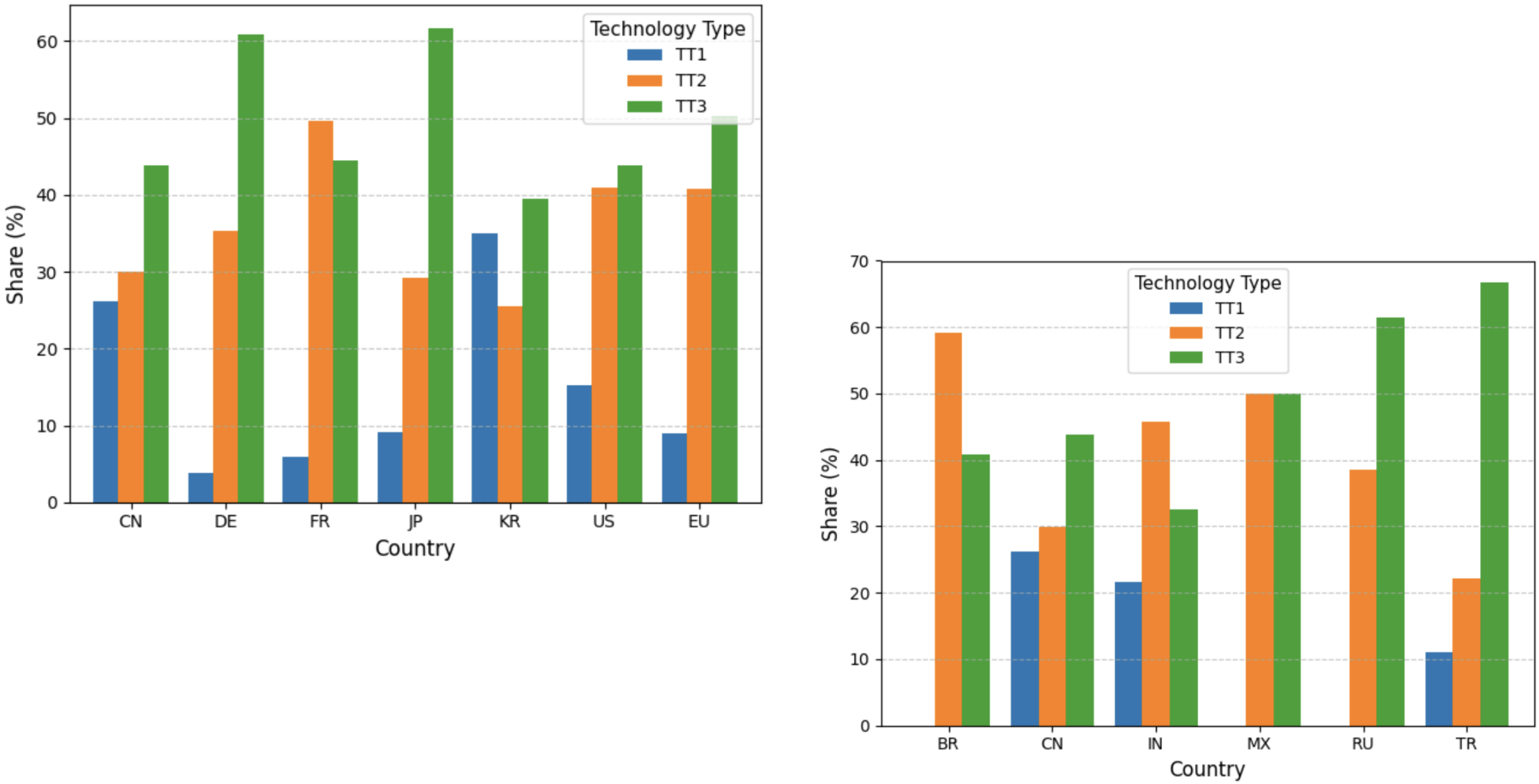
What about the global South?

Income group	TT1	TT2	TT3	Total
High income	15,6%	38,7%	45,8%	92,5%
Upper middle income	25,4%	30,7%	43,8%	7,1%
Lower middle income	19,5%	47,7%	32,9%	0,4%

Upper middle Income

country	number	share
China	2670	97,1%
Brazil	44	1,6%
Türkiye	9	0,3%
Mexico	8	0,3%
Argentina	4	0,1%
Malaysia	3	0,1%
Colombia	2	0,1%
Costa Rica	2	0,1%
Iran, Islamic Rep.	2	0,1%
Thailand	2	0,1%
Ukraine	2	0,1%
South Africa	2	0,1%
Gabon	1	0,0%

Figure 4. Distribution of TTT per applicant country



RTA (Revealed Technology Advantage): Relative technological specialization

TABLE 3: Positive RTAs: Green Technologies

Y02A	Adaptation	UK, USA
Y02B	Buildings	UK, EU
Y02C	GHG capture and storage	UK, EU, USA
Y02D	Green-ICT	China, USA
Y02E	Energy	China, EU, Japan
Y02P	Production	Japan
Y02T	Transport	China, UK, EU, Japan
Y02W	Waste	China, EU
Y04S	Smart Grids	UK, USA

TABLE 4: Positive RTAs: General Purpose Technologies

ARTIFICIAL INTELLIGENCE	USA
AUTONOMOUS SYSTEMS	EU, China, Japan
BIG DATA	EU, USA
CLOUD COMPUTING	USA
INTERNET OF THINGS	UK, China, USA
ROBOTICS	EU, UK, Japan

Source Table 3and 4: own elaboration based on WIPO

RTA (Revealed Technology Advantage) index provides an indication of the relative specialization of a given country in selected technological domains, based on patent applications

Patent quality: forward citations

- Forward citations occur when a patent refers to another one, signaling that the original patent has been influential in the development of subsequent technologies.
  - The higher the number of forward citations, the more valuable the patent.
  - Share of most-cited patents is the number of most-cited patents for each country in each technology divided by the total number of most-cited patents in that technology.

- US patents are more cited in every technology.
- EU patents are more influential than Chinese ones.

TABLE 5: Top 10% most cited digital green patents by GPTs, 2011–2020

GPTS	COUNTRY	# OF PATENTS	# OF MOST-CITED PATENTS	SHARE OF MOST-CITED PATENTS (%)
Artificial Intelligence	China	676	21	3.51
	EU	1076	100	16.72
	UK	185	4	0.67
	Japan	1234	58	9.70
	USA	5285	415	69.40
Autonomous Systems	China	478	31	10.76
	EU	967	64	22.22
	UK	138	2	0.69
	Japan	954	8	2.78
	USA	3001	183	63.54
Big Data	China	68	1	1.49
	EU	196	9	13.43
	USA	731	57	85.07
Cloud Computing	China	209	4	1.16
	EU	329	58	16.81
	Japan	270	12	3.48
	USA	2639	271	78.55
Internet of Things	China	211	6	1.97
	EU	223	36	11.80
	UK	96	2	0.66
	Japan	371	48	15.74
	USA	1814	213	69.84
Robotics	China	242	11	2.61
	EU	720	63	14.93
	UK	159	3	0.71
	Japan	920	45	10.66
	USA	2205	300	71.09

Note: this table only considers patents registered at USPTO. | Source: own elaboration based on WIPO

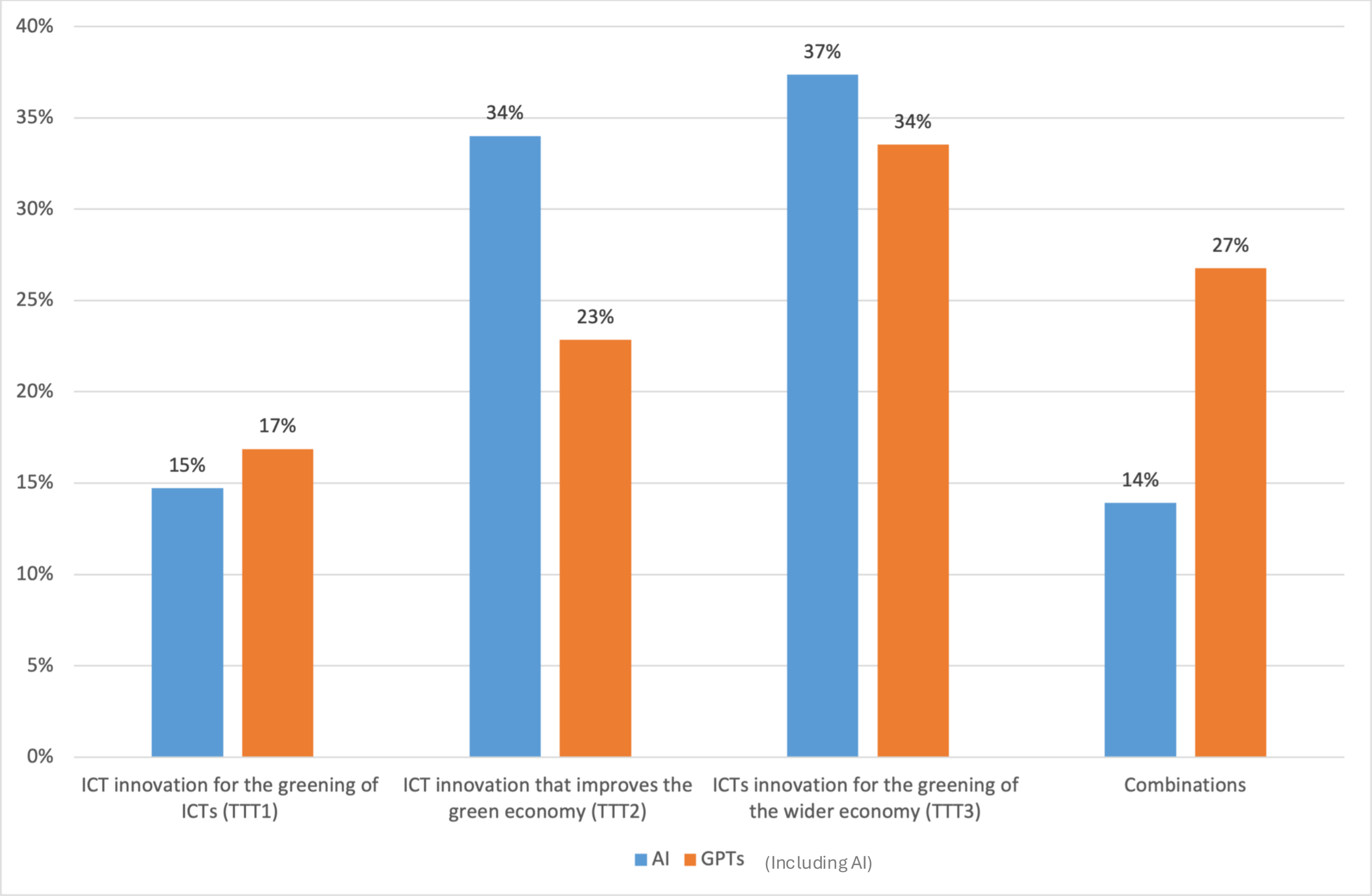
Artificial Intelligence and Climate Change

- The relationship between artificial intelligence and climate change is both **positive** and **negative**:
  - AI has potential intrinsic adverse effects: increased carbon emissions from computing and data centers.
  - These effects may, however, be offset by the application of AI to various climate mitigation and adaptation domains.
- But the positive effects are not automatic, nor are existing solutions necessarily the most relevant ones – especially in the Global South.
- Hence the need for **policy** and governance frameworks.

AI-Driven TTTs

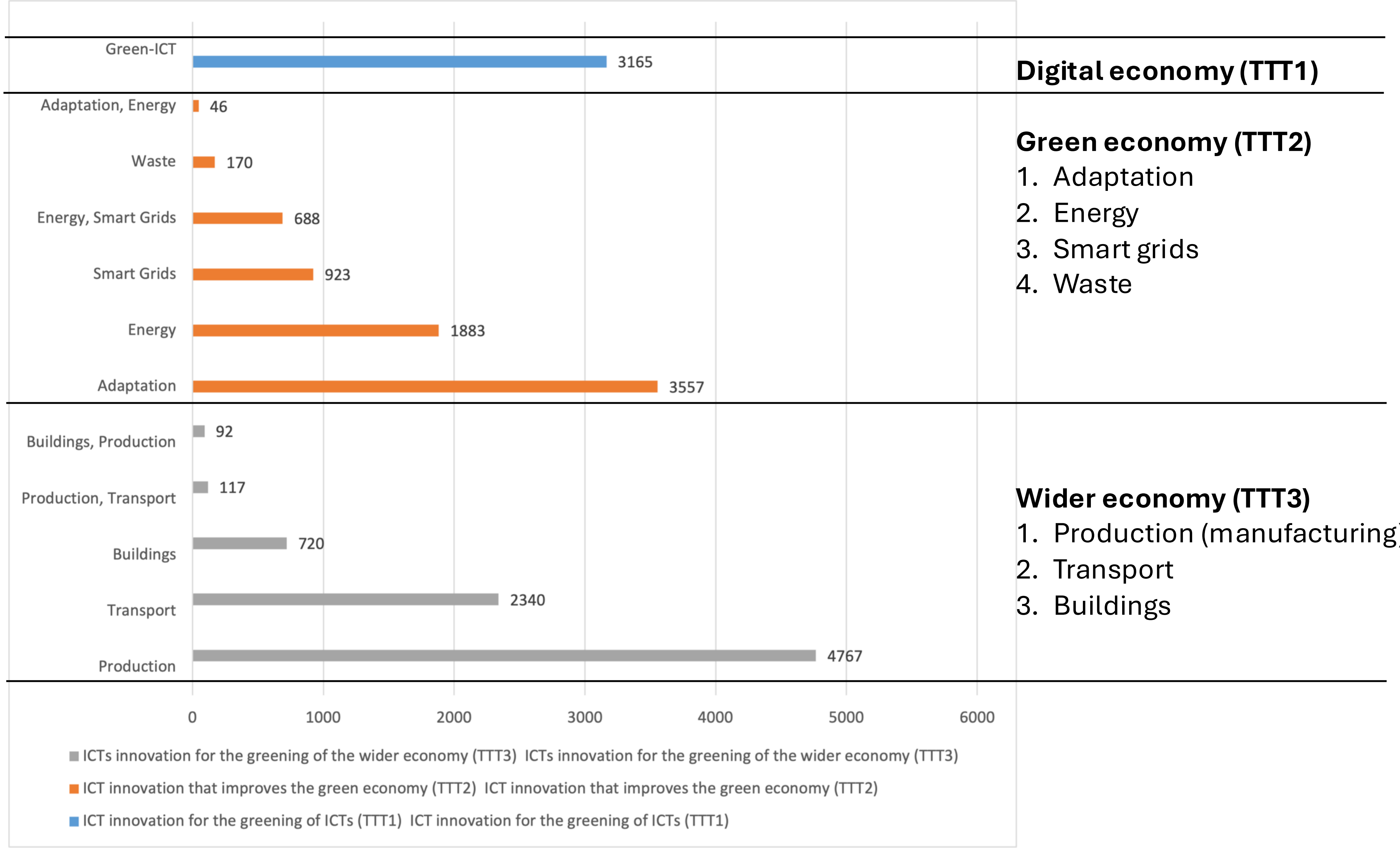
Type of TTT	Domains	Examples
AI for ICT greening (TTT1)	• Computing • Communication networks • ICT equipment	• Optimize cooling and energy use in data centers • Dynamic allocation of computational resources
AI for improving the green economy (TTT2)	• Adaptation • Carbon capture and storage • Energy • Smart grids • Waste	• Predicting climate change impacts • Monitoring and preventive maintenance of renewables • Predicting and managing energy demand, reducing peak load on the grid
AI for greening the wider economy (TTT3)	• Buildings • Production • Transport	• Optimizing heating, cooling, and lighting, reducing energy consumption • Improving manufacturing processes to use fewer resources and produce less waste • Optimizing routes and maintenance for transport fleets, enhancing fuel efficiency

Main AI application domains



- Compared to other digital technologies, AI has a more pronounced focus on solutions for the green economy (TTT2).

AI-TTT with Y02/Y04 tag by GPTs category (# applications)



Digital economy (TTT1)

Green economy (TTT2)
1. Adaptation
2. Energy
3. Smart grids
4. Waste

Wider economy (TTT3)
1. Production (manufacturing)
2. Transport
3. Buildings

Distribution of climate-focused artificial intelligence patents across country groups

Country	# patents	% of total
United States	**30882**	**46,34%**
Japan	11825	17,74%
EU	**10194**	**15,3%**
Germany	4543	6,82%
France	1632	2,45%
Netherlands	843	1,25%
Italy	705	1,06%
Sweden	680	1,02%
UK	**1841**	**2,76%**
Korea	3718	5,58%
China	**3323**	**4,99%**
Rest of countries	4865	7,30%
Total	**66.648**	**100%**

High Income	94,1%
Upper middle income	5,4%
Lower middle income	0,5%
Low Income	0,0%

91% Chinese patents

Country	# patents	% of total
China	3323	91,5%
Brazil	87	2,4%
Turkey	61	1,7%
Mexico	61	1,7%
Russia	54	1,5%
Rest of countries	46	1,3%
Total	**66.648**	**100%**

Summary of the key findings

- Globally, the twin transition is still at a very early stage but growing. There is still a relatively weak connection between ICTs and green technologies.
- USA is the world leader in TTTs, largely reflecting the overall superiority in digital technology innovation, followed by Japan and EU, although with a significant gap.
- China remains a relative latecomer in the TTT field.
- The analysis of the quality of patents shows that China has less impactful digital green patents compared to USA, EU, and Japan.

Cooperation or decoupling?

- In the field of the twin transition technologies there is a delicate balance between cooperation on common challenges and competition to safeguard economic interests and values.
- Decoupling in digital green technologies, for example by means of export controls, seems both unrealistic and counterproductive because these are technologies aimed at tackling climate change and biodiversity loss with a clear global interest.
- Instead of decoupling, China and the EU (as well as the rest of the world) should increase public R&D investments and provide incentives to private investors to strengthen the existing areas of technological leadership, at the same time deepening cooperation with relevant partners.
- Especially in non-competitive fields, such as green digital technologies, competition needs to be combined with collaboration.
- It is essential to maintain a long-term perspective, which might offer a different set of opportunities in a rapidly changing global environment: cooperation at the technical level and exchanges in concrete domains should always remain possible.

Implications for the Global South

- **Context specific solutions**: The danger is that TTTs are mainly/only shaped by lead-market conditions and do not account for the specific circumstances of low and middle-income countries, such as less efficient electricity grids or more labour-intensive production techniques. Need for context-specific solutions.

- **Support solutions in and for the Global South:** In global public policy more attention needs to be given to the environmental potential of digital technologies as a global public good. Incentives and support for firms to address problems/conditions that are specific to the countries and domains where the mitigation potentials and adaption needs are greatest.

- **Differentiated strategies:** Some emerging economies combine ICT capabilities and enormous environmental leapfrogging potential (China, India, Brazil, South Africa…) while other countries are characterized by more adaptation need and more limited local capacity.

[REVERSE DEPENDENCY: MAKING EUROPE’S DIGITAL TECHNOLOGICAL STRENGTHS INDISPENSABLE TO CHINA]

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