Smart energy transition

Technology convergence of renewable energy and ICT sectors

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Hanna-Liisa Kangas
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Authors: Hanna-Liisa Kangas*, Kimmo Ollikka**, Kim Yukyeong*, Jero Ahola***

*Finnish Environment Institute SYKE
**VATT Institute for Economic Research
***Lappeenranta University of Technology LUT

Smart energy transition

- As the share of weather dependent renewable electricity production such as solar and wind power increases, smart energy solutions are needed to enable the transition and balance the energy markets

- Definition:

"[a transition] toward a smart energy network of the future that is characterized by widespread deployment of **clean energy technologies** and **intelligent energy management technologies**". (Zhang et al. 2015, 6686)

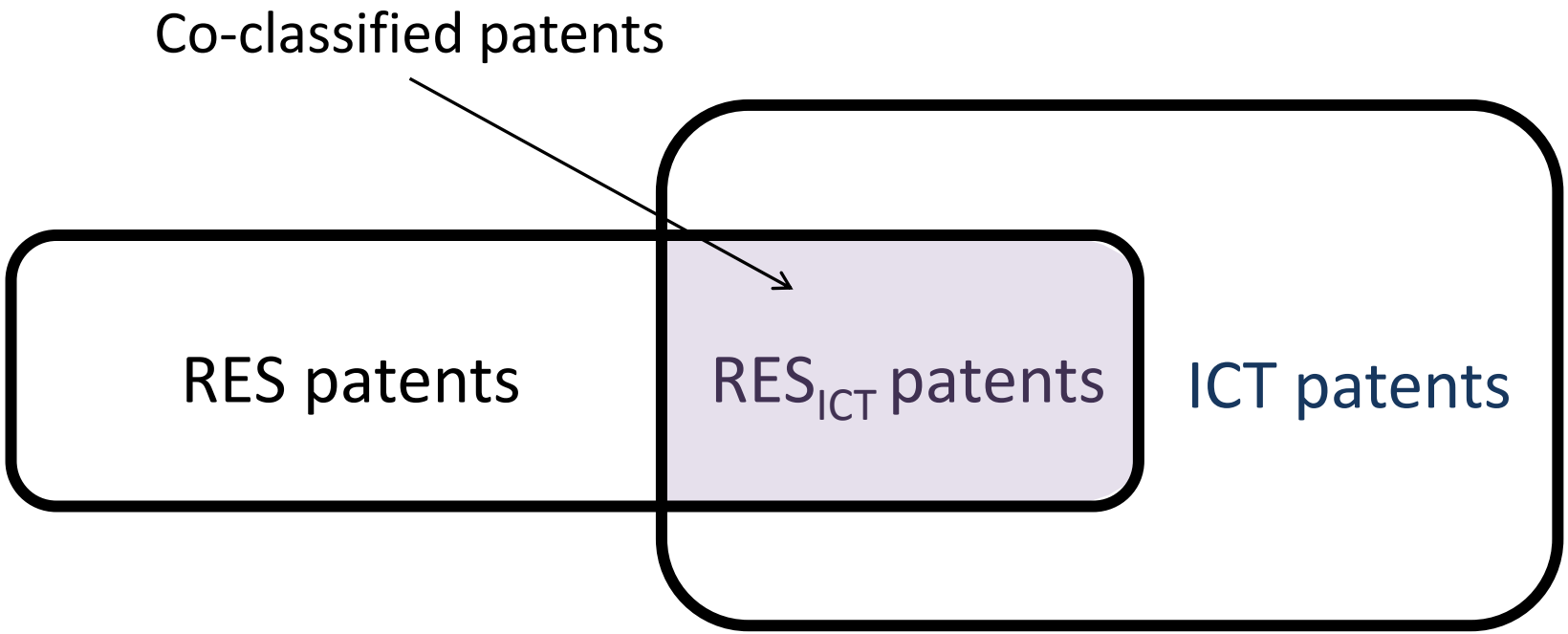
Technology convergence

- The blurring of boundaries between at least two areas of technology
- A necessary step when developing new cutting edge technologies
- Opens up the possibility for new business models, growth possibilities, markets, and customers for companies

Indicator of convergence: patent co-classifications

- All patents are arranged to different technology classes by examiners of patent offices according to their technical features
- Same patent can be classified to multiple technology fields, i.e. co-classified.
- If co-classification of formerly separate technology fields increases, it can be an indicator of technology convergence
- Co-classification is the most often used and commonly accepted method of measuring technology convergence

Patent co-classifications



The aim of the study

- Our aim is to study the convergence of renewable energy and ICT sectors
- Our research questions are:

(1) looking at the co-classification of renewable energy and ICT sectors, are there any signs of convergence between the sectors?

(2) Are there differences in the convergence with ICT between the studied technologies, i.e. solar PV and wind power?

Studied technologies (global data)

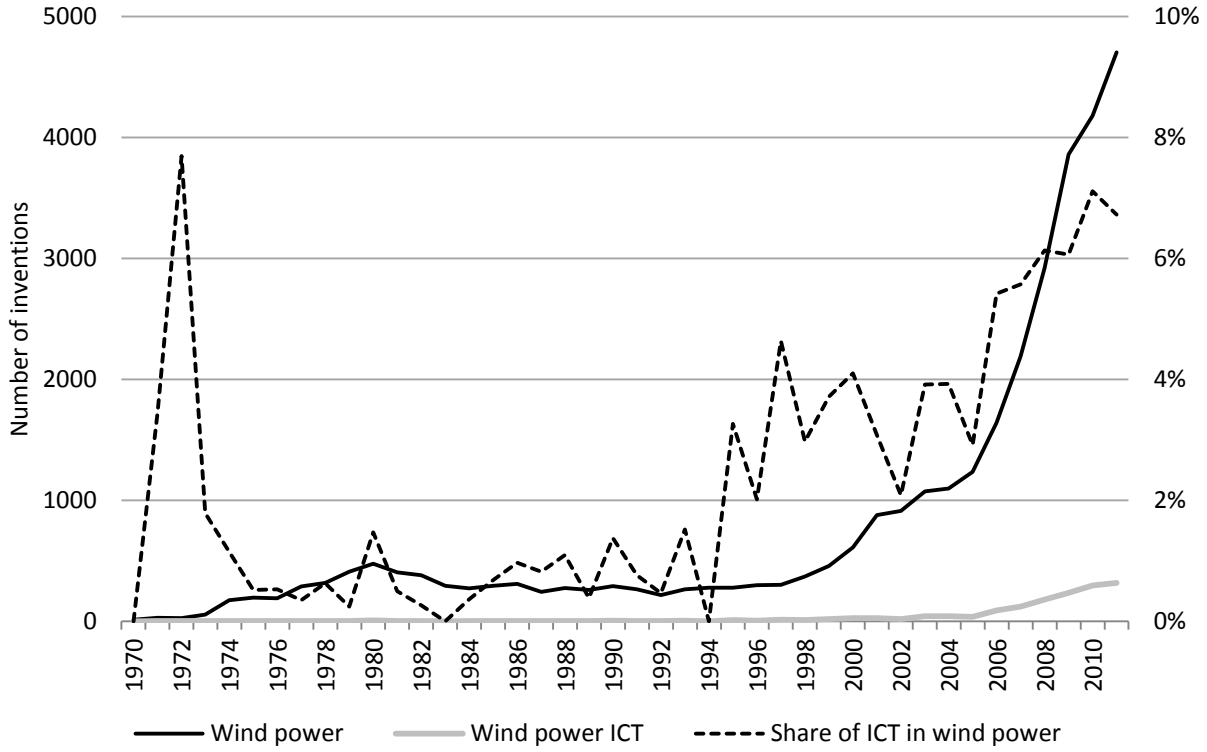
Technology	Classification	Sub-category	IPC or CPC Codes
Solar PV	CPC Y02E 10/5	PV energy	Y02E 10/50
		PV with concentrators	Y02E 10/52
		Material technologies	Y02E 10/54
		Power conversion electric or electronic aspects	Y02E 10/56
		Maximum power point tracking [MPPT] systems	Y02E 10/58
Wind power	CPC Y02E 10/7	Wind energy	Y02E 10/70
		Wind turbines	Y02E 10/(72, 74)
		Power conversion electric or electronic aspects	Y02E 10/76
ICT	IPC Definition of OECD	Telecommunications	G01S, G08C, G09C, H01P, H01Q, H01S 3/(025,043,063,067,085,0933,0941,103,133,18,19,25), H01S 5, H03B, H03C, H03D, H03H, H03M, H04B, H04J, H04K, H04L, H04M, H04Q
		Consumer electronics	G11B, H03F, H03G, H03J, H04H, H04N, H04R, H04S
		Computer, office machinery	B07C, B41J, B41K, G02F, G03G, G05F, G06, G07, G09G, G10L, G11C, H03K, H03L
		Other ICT	G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N, G01P, G01R, G01V, G01W, G02B6, G05B, G08G, G09B, H01B11, H01J (11/,13/,15/,17/,19/,21/,23/,25/,27/,29/,31/,33/,40/,41/,43/,45/), ~~H01L~~

Wind power and solar PV

- The technologies were chosen due to the rapid increase in their investments and importance
- Only the electricity production technologies were studied (i.e. not consumption, demand response, smart grid integration etc. due to lack of data)
- Modern wind turbines are large complex systems of many rotating subsystems
  - they benefit from new control and optimization technologies (wind power conversion)
- The solar PV system has no complex machinery neither (usually) rotating parts, works silently and needs little maintenance
  - Maximum power point tracking (MPPT) is a software algorithm implemented in solar PV inverter or plant. It controls the production in order to generate the maximum electrical power during the varying conditions and temperatures
  - Solar PV conversion technologies utilize control and optimization technologies

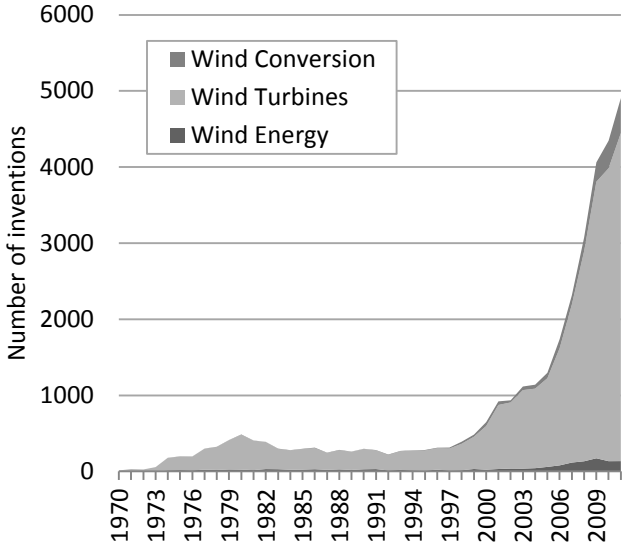
Results: Wind power

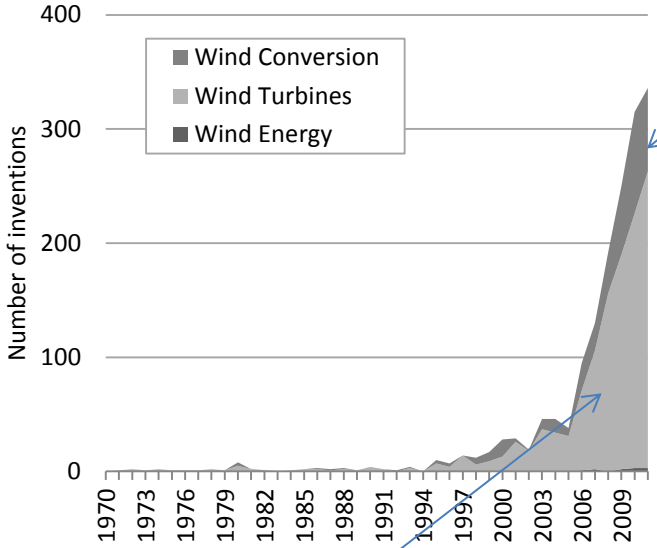
Wind power co-classification



Wind power inventions by technology subclasses:

Total number of inventions (left side) and ICT co-classified inventions (right side).





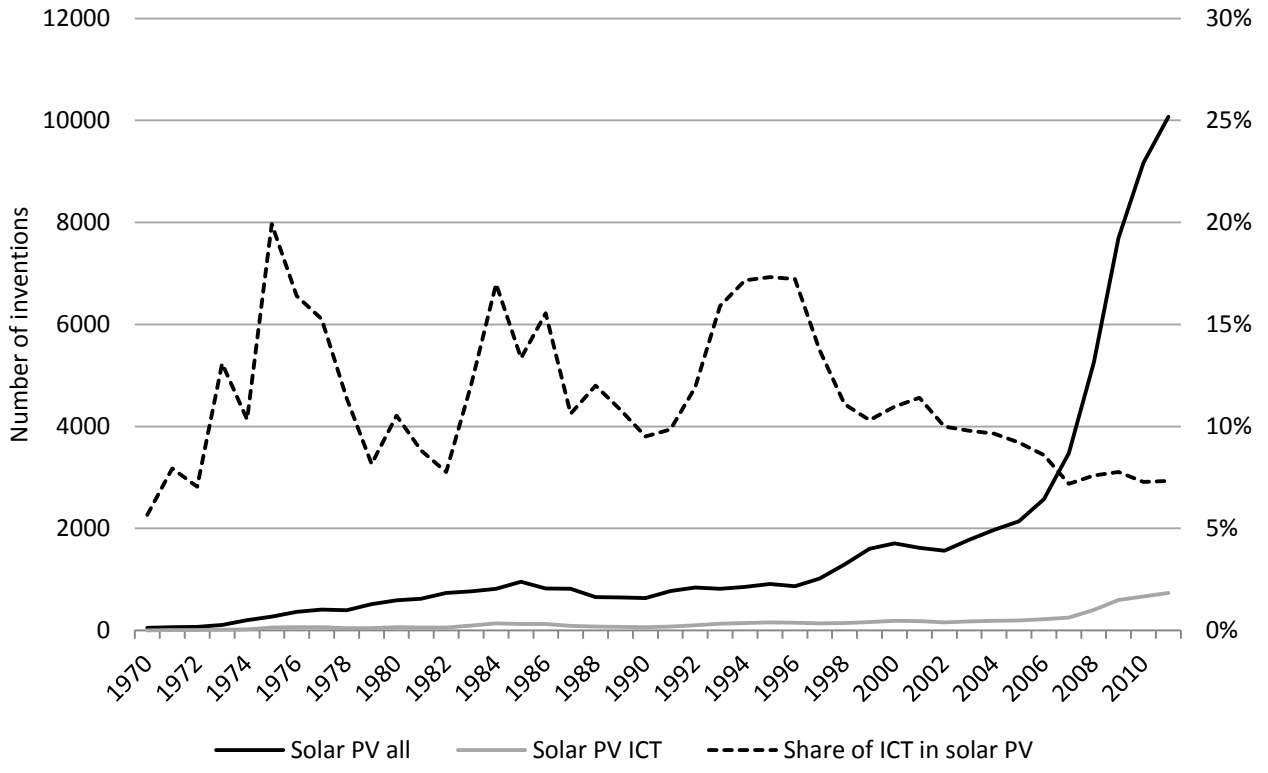
19 % of wind conversion technology innovations are co-classified as ICT

Control, monitor and optimization technologies

4 % of wind turbine technology innovations are co-classified as ICT

Results: Solar PV

Solar PV co-classification



Solar PV subclasses: co-classification with ICT

		Share of all solar PV inventions	ICT co-classification share of inventions
PV energy		47 %	8 %
PV systems with concentrators		11 %	8 %
Materials technologies		36 %	7 %
	DSSC	9 %	3 %
	Organic solar cell	11 %	12 %
	Inorganic solar cell	18 %	5 %
Power conversion		5 %	28 %
MPPT		2 %	84 %

Note: during the studied timeframe solar PV technology developed very rapidly and most inventions improved the ”basic” technologies, where the share of ICT was small

The lowest number of inventions, highest share of ICT

Preliminary regression results

Regressions show that wind conversion and solar PV MPPT are driving the increasing ICT shares, but the drivers for decreasing ICT shares in solar PV are not as clear.

Still work under process.

Dependent variable: Share of co-classified wind power ICT inventions

	(1)	(2)	(3)
constant	-0.202	0.006	0.019***
	(0.142)	(0.004)	(0.005)
wind energy	-0.146		
	(0.133)		
wind turbines	0.233		
	(0.142)		
wind conversion	0.546***	0.582***	-0.747
	(0.116)	(0.093)	(0.386)
1990-2011			-0.017
			(0.009)
1990-2011 * wind conversion			1.420**
			(0.406)
N	42	42	42
LL	121.10	114.84	120.82
F	21.17	39.34	20.73
R2	0.63	0.50	0.62

Note: * p<0.05, ** p<0.01, *** p<0.001

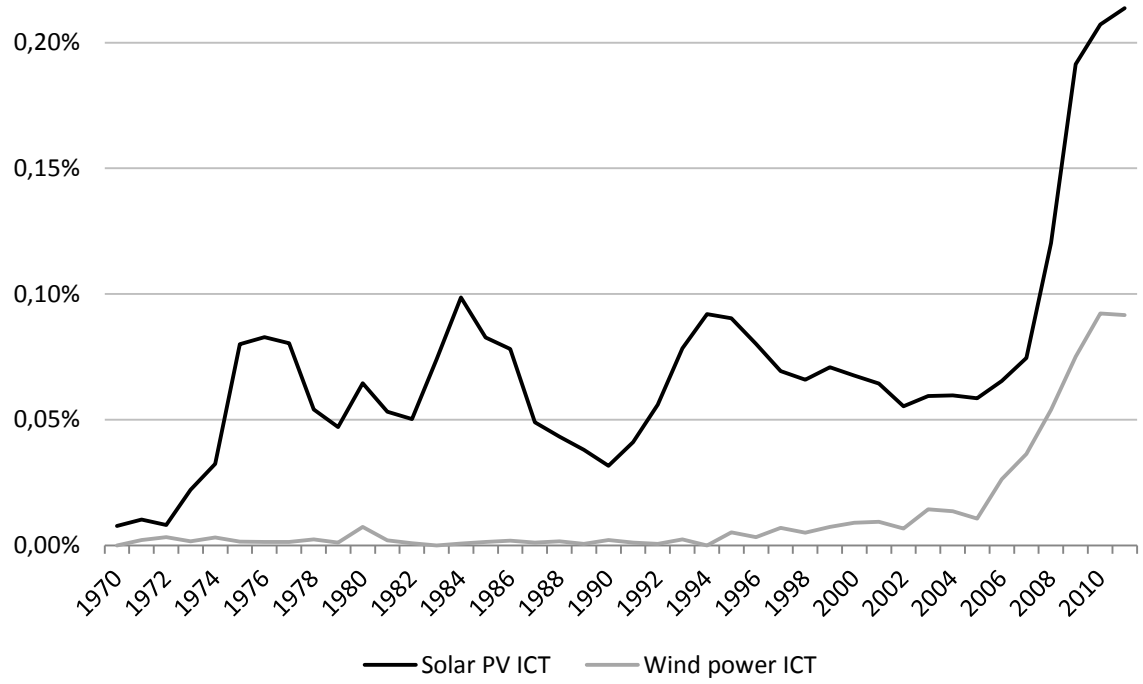
Dependent variable: Share of co-classified photovoltaic ICT inventions

	(1)	(2)	(3)	(4)
constant	0.066	0.084*	0.005	0.098**
	(0.040)	(0.038)	(0.044)	(0.033)
pv concentrators	0.136		0.282*	
	(0.130)		(0.132)	
pv conversion	-0.541		-0.435	
	(0.301)		(0.522)	
pv mppt	1.723**	0.980**	0.754	0.499
	(0.515)	(0.308)	(0.643)	(0.402)
pv materials	0.060		0.246*	
	(0.092)		(0.108)	
- pv materials dssc		-0.320*		0.053
		(0.152)		(0.319)
- pv materials organic sc		0.377*		0.603***
		(0.139)		(0.117)
- pv materials inorganic sc		-0.010		-0.089
		(0.112)		(0.095)
1990-2011			0.051	-0.105
			(0.085)	(0.054)
1990-2011 * pv concentrators			-0.507*	
			(0.235)	
1990-2011 * pv conversion			0.366	
			(0.695)	
1990-2011 * pv mppt			1.030	1.274*
			(0.881)	(0.544)
1990-2011 * pv materials			-0.157	
			(0.180)	
1990-2011 * pv materials dssc				0.283
				(0.353)
1990-2011 * pv materials organic sc				-0.724**
				(0.203)
1990-2011 * pv materials inorganic sc				0.364*
				(0.158)
N	42	42	42	42
LL	88.25	90.96	99.06	111.90
F	3.34	5.07	4.54	11.36
R2	0.27	0.35	0.56	0.76

Note: * p<0.05, ** p<0.01, *** p<0.001

Results: ICT

The share of solar PV and wind power of ICT inventions.



Small shares, but rapid increase after the year 2000

Conclusions

- Clear evidence of wind power and ICT sector convergence was found
  - The wind power sector shows indications of a transition from being almost completely separate from the ICT sector to some convergence with it in all the studied aspects
  - Modern wind mills can take advantage of digitalisation in multiple ways
- Solar PV technologies are utilising ICT increasingly, but the share of ICT does not show a growing trend
  - The major innovations after 1990's were not related to ICT, basic technology development was important and growing faster than ICT related inventions
  - Solar PV technologies have utilized ICT technologies during the whole studied time-frame

Conclusions

→ When implementing innovation and/or energy policy, taking into account the possibilities of RES/ICT interphase is important

→ Especially in Finland (a country with strong ICT-sector) this can be an important factor to increase the competitiveness of the energy sector

→There results represent only the very beginning of smart energy transition

→ When sufficient data are available, the integration with smart grids and consumption should also be studied

Thank you!

hanna-liisa.kangas@ymparisto.fi

ICT convergence studies

- As digitalization has proceeded, the convergence of ICT and other sectors has become a subject of a handful of studies:
  - Pulp and paper and electronics sectors (Karvonen and Kässi, 2011; Karvonen and Kässi, 2013)
  - Biotechnology and information technology (Geum et al., 2012; Kim and Lee, 2013)
  - Convergence of renewable energy and ICT sectors has not been studied so far.