汎用的技術（GPT）と温暖化問題

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ここ１０年ほどの間に、太陽光発電のコストは、急速に減少してきた。だが、急速なコスト低減が起きてきたのは、これだけではない。蓄電池、車載用燃料電池、シェールガス・オイル開発技術等の他のエネルギー技術のコストも同様な急速な低減をした。また、AI、センサー、インターネット通信、情報記憶装置等の、通常はエネルギー技術とは分類されない技術についても、急激な性能向上と、広範なコスト低減が見られている。これらは、エネルギー効率の高い空調・照明技術や、温室効果ガスの少ない精密農業などの形で温室効果ガス削減に寄与する。

以上のような急速な進歩の原動力は、ICT（AI,IOT 等）、ナノテクノロジー、バイオテクノロジーなどの汎用的技術の共進化である。新しい技術は古い技術の組み合わせで生まれる。技術システムは全体として、複雑系として共進化する。技術進歩には蓄積性があり、また加速する。共進化の簡単な例を挙げると、計算機の発達によって、材料のナノスケールのシミュレーションができるようになり、これによって微細加工技術が発達し、更に計算機の能力が発達してきた。これを活用して燃料電池やシェールガス採掘技術が進歩した。

汎用的技術について急速な進歩が現に観測され、今後も加速すると見られていることから、その活用によって大規模な温室効果ガス削減が可能ではないかという議論が起きている。

この排出削減量を見積もるとなると、個々の技術の仕様・コスト・普及量の見通しや、誘発される人間活動の変化を推計しなければならず、容易ではない。仮によい技術が出来てもうまくビジネスモデルが確立出来ない場合もある。以上の理由により、大幅な排出削減という推計から、リバウンド効果によって逆に排出が増加するという推計まで、計算結果には大きな不確実性が伴う。

のみならず、2030 年、2050 年ともなると、どのような技術が普及をするか予想することもできないが、それによるエネルギー消費・温室効果ガス排出削減への効果がきわめて大きい可能性がある。例えば、人工知能を搭載したロボットがオフィスや家庭に普及すると、大幅な省エネが可能になるのではないか？　あるいは、太陽光発電等の設置工事の大半をロボットが担うようになれば、さらなるコストダウンが図れるのではないか？

このような不確実性があるため、運輸部門を例外として、経済全体あるいは部門全体としてどの程度の温室効果ガス排出削減が可能であるかという定量的な見積もりは、今のところ学術論文としてはほとんど存在しない。更なる挑戦的な研究が待たれるところである。

なお適応についても、汎用的技術の進歩による効果は大きいと思われる。既に、ICT の活用によって、自然災害の予測や早期警報等が長足の進歩を遂げ、これによって自然災害への脆弱性は大幅に軽減した。今後もその寄与は大きいだろう。

General Purpose Technologies (GPT) and Climate

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Costs of PV has sharply dropped(International Energy Agency 2017) However, it is not exceptional. Likewise, there have been sharp cost drops in other energy technologies, including battery(Nykvist and Nilsson 2015), fuel cell(Iguma and Kidori 2015), shale gas and oil(Mills 2015). Furthermore, rapid improvement of performance and sharp decline of costs have been observed for many technologies that are not usually categorized as “climate technologies” still they will have immense impacts on GHG emissions. They include Artificial Intelligence (AI), sensors, internet, memory storage, to name a few(IEA 2017)(Holdowsky et al. 2015). Such technological development have been, and will be, contributing to cut GHG emissions in form of various technologies such as smart lighting systems and precision agriculture.

The major driver of such rapid change is the co-evolution of General Purpose Technologies (GPT) consisting of Information and Communication Technologies (ICT) including AI and Internet-Of-Things (IOT), nanotechnologies, biotechnologies, robotics, and so forth(OECD 2017)(World Economic Forum 2015)(Bresnahan and Trajtenberg 1995). New technologies always emerge by the combination of prior arts. As such the technology systems evolve over time as a big complex system. The progress is cumulative and accelerating(Arthur 2009)(Kauffman 2000). To illustrate such co-evolution process by an example, the progress of computer simulation enables us to understand the material science better, then it contributes to upgrading microscale manufacturing technique, and eventually it leads us to much faster computing technologies, and again the advanced computer contributes to other applications.

Discussions have emerged as to how much GHGs can be cut in the future by the rapid progress of GPT. As the visions of industryies, Global e-Sustainability Initiative has reported that ICT has the potential to cut one quarter of global GHG emissions in 2030 (Global e-Sustainability Initiative (GeSI) 2015). The estimate is done by adding up the contribution from use cases of verious technologies, such as e-Health that replaces exsiting medical practices by remote one using ICT. The WBCSD announced that it would aim at halving agricultural greenhouse gases by precision agriculture and biotechnology (WBCSD 2015).

Among academic literature, massive cut of GHG emissions was estimated for the passenger car by the combination of three emerging technologies : self-driving cars, electric cars, and car sharing (Viegas et al. 2016), (OECD/ITF 2015) (Greenblatt and Saxena 2015) assuming low carbon content in electricity. However, there is a possibility that greenhouse gas emissions may rather increase due to improved convenience, and appropriate policy intervention to suppress such rebound effect is necessary to enable substantial emission reduction(Wadud et al. 2016).

The industrial and building sector are also being benefited from GPT(World Economic Forum 2015)(Snatkin et al. 2013). Simlar with the transport sector, generally speaking massive GHG emission cut are enabled by electrification, automation, sharing economy, and improvement in energy and resource efficiency.

All of the above-mentioned technologies can contribute to GHG emission cut. However, estimating the amount of emission cut is not easy due to many uncertainties. They include: the outlook for the technological performance, costs, penetration rate, and the human activities to be induced, to name a few. Even if a good technology is available, business models may not be established successfully in time(Linder and Williander 2017). For the above reasons, the calculation results are subject to great uncertainty. Studies show a wide range of estimates – from drastic emission cut to even the increase in the emissions due to the rebound effect(Larson and Zhao 2017).

While climate policies are often discussed in the time horizon of 2030, 2050, or even beyond, no one can not precisely predict what kind of technologies will be widely used, as the progress is so rapid. Furthremore, it should be noted that all the above estimates do not include many technologies that are not well known as of today. For example, how much emission cut is possible, if there are robots with AI in every office and home, and they manage the energy demand in very intelligent way? Or, how much costs can be cut if robots, instead of human workers, install photovoltaic power systems on the rooftop? As we can not predict how wise AI will be in 2030 (and 2050 !) , we can not predict the performance or costs.

Surely the progress of technologies, in particular that of GPT, will have fundamental impacts on the energy demand, and it will enable massive emissinon cuts. As it is so immense, it is wrong to ignore it in the debate of climate policy. Despite the many uncertainties, estimates are required. So far, quantitative estimates of emission cuts at economy or sector scale have been scarce, particularly in academic literature, except transport sector.

GPT will also have big impacts on adaptation. For example, ICT has been, and will be, instrumental for the forcasts and early warning of natural disasters, thereby greatly reducing the vulnerability(Eakin et al. 2015).