The United Nations Framework Convention on Climate Change (UNFCCC) contemplates mainly two types of technology: adaptation and mitigation.

Adaptation is defined as "adjustment in nature or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities."[16] In other words, adaptation concerns taking measures to reduce the negative effects or to exploit positive ones by making appropriate adjustments. Adaptation technologies include 'soft' forms such as crop rotation patterns and traditional knowledge, 'hard' forms like irrigation systems and drought-resistant seeds, and combinations of both such as early-warning systems.[17]

Mitigation involves finding solutions to reduce emission of greenhouse gases, or to capture or to absorb them in some kind of carbon repository. Marketable or close to marketability technologies include, *e.g.*, renewable energy options (solar panels, wind turbines, biofuels, biomass and hydro-power generation), carbon capture and storage, hybrid vehicles, animal waste management, clean coal technologies, and green buildings.[18]

Green technology embraces a variety of technical fields lowering the adverse impact of climate change. The patent system may provide practical assistance on what constitutes green technology, for example, through its classification system. Current efforts to prioritize and categorize green technology within the patent system are discussed in Chapter IV.

2. Facts and Trends in Green Patent Filing

Barton observes that the basic technical solutions of climate change have long been "off-patent," but that "specific improvements or features" are usually patent-protected.[19] This is in contrast with the pharmaceutical sector where an individual

16 UNFCCC, *Glossary of Climate Change Acronyms*, *at* http://unfccc.int/essential_background/glossary/items/3666.php (last visited Jan. 17, 2011).

17 *See generally* UNFCCC, Technologies For Adaptation To Climate Change (2006).

18 UNFCCC, *Fact Sheet: Why Technology Is So Important*, http://unfccc.int/press/fact_sheets/items/4989.php (last visited Sept. 14, 2010). *Also*, *supra* note 16 (explaining that mitigation in the context of climate change is "a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere").

19 John H. Barton, Intellectual Property and Access to Clean Energy Technologies in Developing Countries: An Analysis of Solar Photovoltaic, Biofuel and Wind Technologies 13 (ICTSD 2007).

patent may have a significant impact in the absence of substitutes and the rightholder tends to have a strong market position.[20]

Total patent applications worldwide have increased by 5% on average annually between 1997 and 2007,[21] but green technology patent filings show a much higher growth rate. Between 2009 and 2010 alone, the number of patents in the clean energy sector granted by the United States Patent and Trademark Office (USPTO) increased by 50%.[22] The European Patent Office (EPO) reported a 27% rise between 2008 and 2009 in clean energy patenting.[23]

Patent holders in the field of clean energy technology are based mostly in member countries of the Organisation for Economic Co-operation and Development (OECD) such as Denmark, Germany, Japan, Korea and the US, but China also ranks relatively high across the clean energy technology sectors.[24] In terms of patent activity by country, Japanese and German applicants are particularly active in solar energy and wind power technology, respectively, while US applicants concentrate on bio, geothermal, hydrogen, fuel cells, carbon capture and storage, and waste-to-energy.[25] Denmark is strong in wind power, Australia in bio energy, and China in solar and hydropower.[26] France, Canada and the UK are actively engaged in hydro, wave and tidal power and waste-to-energy, and the Netherlands in biomass.[27]

Among the various technology sectors, solar photovoltaic – light-to-electricity conversion technology – is of particular interest. Power generation from this basis has doubled every two years since 2002, and related international patent filings under the Patent Cooperation Treaty (PCT) have tripled between 2004 and 2008 (from 460 to 1,411 applications).[28] In view of the substantial increase in such patent applications, innovative thin-film technologies with better material and higher efficiency are likely to be "subject to more extensive patenting" in the future.[29]

In the wind power sector, wind turbine manufacturers are emerging not only from developed countries but also from developing countries. According to a Chatham House Report published in September 2009, the top four wind energy patent owners

20 *Id*. at 4.
21 WIPO, World Intellectual Property Indicators 14 (2009).
22 Heslin Rothenberg Farley & Mesiti P.C., *Clean Energy Patent Growth Index* (June 3, 2010), *available at* http://www.cleanenergypatentgrowthindex.com.
23 EPO, Annual Report 2009 1 (2010).
24 Bernice Lee, Ilian Iliev and Felix Preston, Who Owns Our Low Carbon Future? Intellectual Property and Energy Technologies 12 (Chatham House 2009); for statistics on patent filing in solar energy, fuel cell technology, wind energy between 2001 and 2005, *see* WIPO, World Patent Report – A Statistical Review 44 (2008).
25 *See generally* WIPO, *Patent-based Technology Analysis Report: Alternative Energy* (2009).
26 *Id*.
27 *Id.*
28 WIPO, *Photovoltaic Technology Sunny Side Up*, WIPO Magazine 2-4 (June 2009).
29 *Supra* note 19.

together have 13% of all relevant patents whereas their collective market share for wind turbines is 57%.[30]

3. Increasing Investment and Technology Transfer

Particularly in certain developed countries, companies invest increasingly in green technology business plans and practices.[31] In Silicon Valley, more than 100 green patent technology patents were registered between 2006 and 2008, an increase of 7% over the previous three years.[32] Deutsche Bank predicts an increase in private equity, venture capital and infrastructure investment in climate change.[33] Such investment is propelled by innovation policy,[34] whereby investors want to make sure that what they contribute has appropriate IP protection.[35]

An OECD study reveals that whereas overall green technology innovation is concentrated in developed countries, with Japan, the US and Germany together accounting for 60% of total innovations, innovation in emerging economies such as China and Korea is not insignificant.[36] In terms of international technology diffusion, the percentage of so-called 'exported inventions' (*e.g.*, a patent filed in the US by a German inventor) between 1998 and 2003 suggests that three-quarters of exports occurred among developed countries.[37] Exports of inventions from developed countries to developing countries during the same period were less substantial (17.8%) but growing fast. At 1.5%, technology transfer among developing countries was minimal, leaving important potential for more exchanges in the future.[38]

The least developed countries (LDCs), small island developing states and other non-industrialized nations are vulnerable to climate change as their emissions are

30 *Supra* note 24 at 25. *Cf. supra* note 24 at ix (the spread of ownership varies significantly across the sectors. For example, the top 20 companies in clean coal technology own 42% of total relevant patents whereas the top 20 in concentrated solar power technology have only 12%).

31 *E.g.*, Michael Hasper, *Green Technology in Developing Countries: Creating Accessibility through a Global Exchange Forum*, 1 Duke L. & Tech. Rev. 1, 3-6 (2009) (referring to Bosch and IBM's examples).

32 Joint Venture Silicon Valley Network, Climate Property: A Greenprint for Silicon Valley – 2009 38 (Feb. 2009) (reporting that 9% of all U.S. solar energy patents between 2005 to 2007 were registered in the Silicon Valley area, up from 3% in the mid-90s).

33 DB Climate Change Advisors, Investing in Climate Change 2010: A Strategic Asset Allocation Perspective 11-17 (2010).

34 *Id.*

35 *Supra* note 9.

36 *See generally*, Antoine Dechezleprêtre, Matthieu Glachant, Ivan Haščič, Nick Johnstone, Yann Ménière, OECD, Invention and Transfer of Climate Change Mitigation Technologies on a Global Scale: A Study Drawing on Patent Data (2008).

37 *Id.*

38 *Id.*