Chapter 11
Nanotechnology and Military Attacks on Photosynthesis

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Abstract  Advancing scientific knowledge regarding the photosynthetic process at a molecular level has raised the possibility of widespread artificial photosynthetic projects in the future, for example, for large-scale or ‘off-grid’ renewable energy and food production. The value that these projects would have to states and the global community, attracts the possibility that artificial photosynthesis, and the photosynthetic process in general, may become ‘direct’ military targets. This chapter explores the extent to which the existing principles of the law of armed conflict, international environmental law and the ENMOD Convention are capable of regulating a direct attack on natural or artificial photosynthesis. In particular, it examines whether the basic principles of international environmental law prohibit direct manipulation of natural or artificial photosynthesis and are applicable during warfare. It then analyses whether natural photosynthesis may be protected from direct military attack under Articles 35(3) and 55 of Additional Protocol I or under the ENMOD Convention.

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11.1 Introduction

Under the international law of armed conflict, centralised energy supplies (such as electricity power stations) have often been targeted as 'military objects' which contribute to military action and whose destruction or neutralisation legitimately offers a military advantage. Thus, during World War II Allied Lancaster bombers famously attacked the hydroelectric dams of Germany’s Ruhr and Japanese planes attacked petrol depots at Pearl Harbour. During the Iran-Iraq war over 400 oil tankers were attacked in the Persian Gulf between 1980 and 1987 and over 2 million tonnes of oil were spilled into the sea in 1984 alone. Electricity generating stations were attacked by United States (US) forces during the 1991 Persian Gulf conflict and by the North Atlantic Treaty Organisation (NATO) in the 1999 Kosovo crisis.

Given this background, it is only to be expected that photosynthesis, as the prime natural energy-generation and storage process, may directly or indirectly become a military target. Photosynthesis, after all, is critical for the production of food, energy in forms such as oil, coal, natural gas and shelter (i.e., through wood) in most parts of the world. As one notorious instance of such attacks in the pre-nanotechnology era, as will be examined below, photosynthesis was targeted indirectly through the military use of defoliants (such as Agent Orange) in the Vietnam War.²

Yet the time is coming when, without adequate international legal protection, the process of photosynthesis may 'directly' become a military target in more sophisticated ways made possible by the use of nanotechnology. A key factor to this issue is that scientific researchers are on the threshold of being able to fully and precisely characterise the photosynthetic process at the molecular level.³ This is likely to lead rapidly to breakthroughs improving the process of photosynthesis that will be of great benefit to humanity and its environment.⁴ One promising example involves nanotechnology-based approaches that allow human structures

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¹ Antoine 1992, p. 530.
² Stellman et al. 2003.
⁴ Faunce 2012a.
on the Earth's surface (buildings, roads and vehicles) to perform photosynthesis artificially, providing hydrogen fuel from sunlight-driven water splitting, and food or fertilizer from carbon dioxide absorption, more efficiently than plants.\(^5\)

Yet, there are always troubling risks associated with every scientific advance. Our increased understanding and ability to replicate and improve photosynthesis, combined with advanced applications of nanotechnology, may result in the core energy-producing components of that critical natural process becoming a potential military target. The use of novel approaches to attack the process of photosynthesis (such as those based on nanotechnology) is potentially more wide-reaching in terms of ecological and societal damage than chemical-based defoliants. Indeed, artificial photosynthesis provides a case study of how the law of armed conflict will need to deal with nanotechnology, not only as a source of weaponry and weaponised effects, but also in terms of considerations for targeting, collateral damage, and military objective status. The relationship between the law of armed conflict and nanotechnology is not all one way—that is, it is not only about weaponisation, but also has reverse implications in terms of assessing the legitimacy of a particular target, and what factors must be considered in terms of collateral damage estimation and foreseeability. This same debate is also reflected in arguments regarding the military status of some cyber capabilities.\(^6\)

This chapter explores, consequently, the extent to which the law of armed conflict is capable of regulating a direct or indirect attack on core components of the photosynthesis process (in its 'natural' or 'biological' and nanotechnology-enhanced or otherwise 'artificial' forms). In doing this, it will investigate the extent to which the basic principles of the law of armed conflict may work with international environmental law obligations, in particular the precautionary principle and the ban on hostile use of environmental modification techniques under the ENMOD Convention,\(^7\) to prevent natural or artificial photosynthesis becoming a direct military target in armed conflict.

### 11.2 Photosynthesis and Energy Security

More solar energy strikes the Earth's surface in one hour of each day than the energy used by all human activities in one year.\(^8\) At present, the average daily power consumption required to allow an adult citizen to flourish with a reasonable standard of living (or soldier to operate in standard conditions) is about 150 kW/day. Much of this power is devoted to transport (up to 40 kW/day), heating (up to

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5 Faunce et al. 2013.

6 See, Chap. 5 by Boothby in this volume.

7 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, 18 May 1977, 1108 UNTS 151 (entered into force 5 October 1978) ('ENMOD Convention').

40 kW/day) and electrical appliances (up to 18 kW/day), with the remainder lost in electricity conversion and distribution. World energy consumption is currently in the region of 450 exajoules per year, but vastly more than this is the solar energy potentially usable at approximately 1.0 kW/m² of the Earth, which equals with $3.9 \times 10^9$ exajoules per year. If we take into account the Earth’s tilt, diurnal and atmospheric influences on solar intensity, power from the solar source becomes approximately 110 W/m². The primary process on the Earth for converting this solar energy into power for human activities is photosynthesis.

Photosynthesis, the ultimate source of our oxygen, food and fossil fuels, has been operating on this planet for 2.5 billion years. Photosynthesis creates a global annual carbon dioxide flux of $124 \times 10^9$ tonnes per year, and an annual oxide flux of up to $10^11$ tonnes per year. In its present technologically-unenhanced, biological form, photosynthesis globally traps around 4,000 exajoules per year of solar energy in the form of biomass. The global biomass energy potential for human use from photosynthesis is approximately equal to human energy requirements (450 exajoules per year).

The social and political transition towards renewable or sustainable energy technologies for energy security has focused separately on solar photovoltaic systems (for grid-based electricity with many utilising nanotechnology to increase efficiency of light capture) and natural photosynthesis in the form of mass-produced biofuels for transportation. This separation creates major drawbacks. The push towards biofuels is stalling as mono-cultural mass production destroys local agriculture and because of its limited capacity to generate power or produce low-carbon transport fuels. Photovoltaic energy systems are improving their efficiencies (through, for example, thinner silicon films using nanotechnology) and the cost of the electricity they produce is nearing or has past grid parity in many states. But they are not an ‘off-grid’ solution and so do not deal with the significant portion of the economy utilising carbon-based transport fuels, neither do they presumptively encourage new community-based energy governance patterns more likely to emphasise environmental sustainability. Even large solar farms (for example with 200 square metres per person with 10% efficiency solar panels) only produce up to 50 kW/day per person. This is still a long way short of the

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150 kW/day average level of consumption in developed countries and does not address the problem of power storage for night use and transport.

In this context it is likely that the capacity of scientific research to increase the efficiency of natural photosynthesis will become a growingly prominent focus of energy security concerns. This will thereby increase the likelihood that this energy-producing process will become of military interest.\textsuperscript{19}

Natural photosynthesis is currently on the doorstep of being fully characterised at the molecular level. Higher structural resolution and computation analysis down to 1.9 ångströms or $1.9 \times 10^{-10}$ m is clarifying the water substrate binding sites on PS-II, which is a central component of the process by which sunlight splits water into hydrogen and oxygen.\textsuperscript{20} Such enhanced, fundamental characterisation of photosynthesis may lead to its substantial and imminent improvement with the use of nanotechnology as an entirely non-biological sustainable energy system capable of being engineered into roads, buildings and vehicles.

Artificial photosynthesis (as this field is generally called) may become a dominant nanotechnology-based source of fuel and food globally and as part of this a means of supporting military action and therefore a military target. Artificial photosynthesis has a historical connection with the military, which began in the Cold War. It was part of what was parodied in the 'Dr Strangelove' film as the 'mine-shaft' gap: the plan to enhance the capacity of the US to keep its politicians, senior industrial and military people alive during a nuclear winter.\textsuperscript{21}

Researchers are now actively re-designing photosynthesis to achieve, for example, low cost, 'off-grid', direct (without intermediate energy carriers) conversion of sunlight, water and carbon dioxide into fuel for heating and cooking.\textsuperscript{22} One such approach is to genetically manipulate or even synthetically reproduce photosynthetic plants and bacteria to enhance their light capture and carbon absorption activities.\textsuperscript{23} Another (with more wide-reaching societal and environmental consequences) is to use nanotechnology to artificially create and enhance three main components of the photosynthetic process: light capture, water splitting and carbon dioxide absorption.

The development of artificial photosynthesis involves greater insights into how photosynthesis works, which may provide novel means of warfare to, for example, directly attack, in new and sophisticated ways, that process in either its natural or artificial forms and thus disable or modify food and energy production regionally. Each component of artificial photosynthesis is likely to involve the use of nanotechnology,\textsuperscript{24} and each could become the focus of a direct military attack.

\textsuperscript{19} Faunce et al. 2013a.
\textsuperscript{20} Hillier and Wydrzynski 2008, p. 306.
\textsuperscript{21} Faunce 2012.
\textsuperscript{22} Hurst 2010.
\textsuperscript{23} Ragauskas et al. 2006.
\textsuperscript{24} See generally, Faunce 2012.
Global deployment of nanotechnology-based artificial photosynthesis is likely to have a significant impact on critical survival issues with direct implications for the exacerbation of military tensions as global population grows towards 10 billion by 2050 and energy consumption rises over 600 exajoules per year. Artificial photosynthesis, for example, is directly relevant to the 2009 Copenhagen Accord, a non-binding political agreement that recognised the critical impacts of population growth and fossil fuel-driven climate change on future society, as well as the need to establish a comprehensive adaptation program including international support for those countries most vulnerable to its adverse effects. Artificial photosynthesis is also relevant to other important internationally agreed targets to improve access to necessary fuel and food as expressed in the United Nations (UN) Millennium Development Goals.

Artificial photosynthesis, if applied equitably, could reduce regional military tensions by assisting crop production on marginal lands, reducing atmospheric CO₂ levels, lowering geopolitical and military tensions over fossil fuel, food and water scarcity, and creating carbon-neutral hydrogen fuel for domestic, community and industrial storage. One model for globalising nanotechnology-based artificial photosynthesis involves bio-mimetic polymer photovoltaic generators plugged into the national electricity grid to power hydrogen fuel. This model has the advantage of the ‘light’ and ‘dark’ reactions being uncoupled in relation not only to energy/material flow balance, but also to the requirement to be co-located in space. Such an uncoupling will vastly extend the area for capturing light over otherwise barren land, and also allow the elimination or reduction of molecular oxygen in artificial photosynthesis reactions, enhancing longevity of the components.

Another model emphasises the greater potential for individual and community economic autonomy implicit in micro or local generation of fuel and food through artificial photosynthesis products installed as a policy priority on all roads, buildings and vehicles. Even under such a model, large artificial photosynthesis facilities providing fuel for industry or backup supply can still be preferentially located near large sources of seawater, carbon dioxide, waste heat, high solar irradiation and in proximity to end-use facilities. Geo-engineering as a response to anthropogenic climate change could, for example, include the designing of systems to supercharge photosynthesis through genetic modification of plants.

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26 For the first time, all major carbon dioxide emitting countries agreed to a target of keeping global warming to less than 2 °C above pre-industrial levels. It contained important undertakings concerning mitigation including the Copenhagen Green Climate Fund and establishing a mechanism to accelerate renewable energy technology development and transfer.
27 GA Res 55/2 (18 September 2000).
28 Pace 2005.
29 Pace 2005.
30 Faunce et al. 2013.
31 Bodie 2010, p. 305.
Consideration of the positive and negative impacts of global artificial photosynthesis on national and international security is a thought experiment in which solar fuels created through humanity’s capacity to fully understand natural photosynthesis processes and enhance, particularly through nanotechnology, the operation of photosynthesis can be harnessed to dissipate sources of conflict by enabling micro or local generation of food and fuel. Such micro or local generation of food and fuel will challenge the present paradigm of centralised fossil-fuel oriented power generation controlled by multinational corporations (either directly or through influence on the state policy) that increases geopolitical tensions. Such prospect, however, is unfortunately far from being realised. It is more likely, in the interim, that increased scientific understanding of photosynthesis at the molecular level could be turned into a hostile use as a means of disrupting natural photosynthesis in more sophisticated ways than has previously been the case. This squarely raises for consideration the legal assessment of military attacks that are designed with a view to localised disruption of photosynthesis, creating a cascade of direct and indirect effects.

11.3 Indirect Military Attacks on Natural Photosynthesis

Historically, indirect attacks on natural photosynthesis can be traced back to the ‘scorched earth’ policies traditionally adopted by armies to deprive their opponents of access to agricultural produce. The British military used the chemical 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) to destroy jungle-grown crops against the insurgency in Malaya soon after World War II.\(^\text{32}\) As well as the use of such plant toxins, depriving an agricultural region of water or even sunlight (i.e., by producing dense, prolonged local smoke or in the future by orbitally positioning mirrors that reflect back the sun’s rays) would fall into this category of indirect attacks on natural photosynthesis.

In the 1960s the US Defense Advanced Research Project Agency (DARPA) carried out ‘Project Agile’, which was instrumental in the US development of herbicides as a weapon.\(^\text{33}\) DARPA supported tests on combinations and concentrations of herbicides; calibration studies of the spray delivery system to achieve the desired spray rate and minimisation of drift.\(^\text{34}\)

One of most well known military attacks on natural photosynthesis involved the use of Agent Orange and other environmental modification techniques during the Vietnam War.\(^\text{35}\) Between 1961 and 1971 herbicide mixtures (nicknamed ‘Agent Orange’ because of the coloured identification band painted on their 208 litre

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\(^{32}\) Cecil 1986.

\(^{33}\) Furukawa 2004.

\(^{34}\) Stellman et al. 2003.

\(^{35}\) Wiersma 1970.
storage barrels) were used by US and Republic of Vietnam forces to defoliate forests and mangroves, to clear perimeters of military installations and to destroy "unfriendly" crops as a tactic for decreasing enemy food supplies. The majority of Agent Orange attacks were directed against forest and woodland cover, but 10 per cent of attacks were directed against crops. About 65% of the herbicides contained 2,4,5-T, which was contaminated with varying levels of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD).

The use of Agent Orange in the Vietnam conflict led the UN General Assembly to restating its position that the 1925 Geneva Protocol prohibited "[a]ny biological agents of warfare—living organisms, whatever their nature, or infective material derived from them—which are intended to cause disease or death in man, animals or plants, and which depend for their effects on their ability to multiply in the person, animal or plant attacked". In its resolution, the General Assembly stated that the 1925 Geneva Protocol embodied the generally recognised rules of international law, suggesting that the prohibition on chemical and biological attacks designed to cause disease in plants (and so indirectly attack photosynthesis) had become part of customary international law. After the Vietnam War, the US support declined for use of chemical defoliants such as Agent Orange. By executive order the US renounced in 1975 the "first use of herbicides in war except use, under regulations applicable to their domestic use, for control of vegetation within U.S. bases and installations or around their immediate defensive perimeters".

The use of Agent Orange is an example of one state indirectly attacking the capacity of another's citizens to enjoy the benefits of photosynthesis. Such an attack on agricultural areas and crops would now violate Article 54(2) of Additional Protocol I, regardless of whether its aim was civilian starvation or displacement, which states that:

It is prohibited to attack, destroy, remove or render useless objects indispensable to the survival of the civilian population, such as foodstuffs, agricultural areas for the production of foodstuffs, crops, livestock, drinking water installations and supplies and irrigation works, for the specific purpose of denying them for their sustenance value to the civilian population or to the adverse Party, whatever the motive, whether in order to starve out civilians, to cause them to move away, or for any other motive.

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38 Zierler 2011.
39 GA Res 2603-A (XXIV) (16 December 1969); Protocol for the Prohibition of the Use of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare, 17 June 1925, 94 LNTS 65 (entered into force 8 February 1928) ("Geneva Protocol").
41 Executive Order 11850, 8 April 1975.
42 Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977, 1125 UNTS 3 (entered into force 7 December 1978) ("Additional Protocol I").
Such an attack would also breach customary international law requirements that the use of force be necessary and proportionate to a military objective. As the International Court of Justice held in Nuclear Weapons, '[r]espect for the environment is one of the elements that go to assessing whether an action is in conformity with the principles of necessity and proportionality'.

11.4 Direct Military Attacks on Natural and Artificial Photosynthesis

Detailed characterisation of the process of photosynthesis, as mentioned, is now making possible direct military attacks upon it in either its natural or artificial (improved or non-biological) forms. Three hypothetical scenarios initially appear worthy of consideration in this context.

First of all, a nanotechnology or synthetic-biology-based attack can potentially be made on the core components of natural photosynthesis to gain military advantage in a particular region. The attack utilises weapons developed from an enhanced understanding of the process of photosynthesis. In this scenario, a self-replicating nanoparticle or synthetic virus could be used by the military (or by terrorists) to disrupt a core component of the process of natural photosynthesis in order to reduce fuel and food supplies available to enemy combatants in a particular region. As an intended or unintended consequence, this 'weapon' could spread through the target country or to other nations within the region, preventing plant growth in both agricultural and natural contexts. Variants of such an attack could involve rogue genes being used to destroy algal or synthetic bio-fuel systems, by infiltrating and harming natural photosynthetic genes. These rogue genes could be seeded from aircraft to disrupt artificial photosynthetic processes in ways designed by the military to adversely impact on the weather and climate in local regions of conflict.

Second, as mentioned, some experts have advocated that the way artificial photosynthesis can outstrip regular photosynthesis is through concentration, industrialisation and economies of scale. Such models have artificial photosynthesis plants (i.e., established on the coast near the desert) sending electricity into power grids in the same way as coal-fired and nuclear power stations currently do. An attack, potentially using engineered nanomaterials, can be made to disrupt or destroy large artificial photosynthesis systems concentrated, for example, to generate hydrogen fuel through solar-driven water-splitting in areas of high solar insulation by the sea.

Third, one of the transformations that nanotechnology is likely to offer society in coming decades involves development of 'off-grid' de-centralised power

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supplies that generate hydrogen fuel rather than electricity. In this scenario, an
attack is made on artificial photosynthesis systems deployed in a distributed
fashion at the local or household level as well as at autonomous military units.
Self-replicating ‘nano-bots’, for example, could be dispersed from rockets, drones
or piloted aircraft which indiscriminately disrupt core components of these sys-
tems within the targeted region.

11.5 Relevant Legal Principles

Direct and indirect military attacks on natural or artificial photosynthesis of the
types discussed above are not free from existing bodies of legal regulation. The
remaining part of this chapter examines the applicability of general principles of
international environmental law and the law of armed conflict, as well as the treaty
that is specifically designed to prevent environmental modification as a method of
warfare—ENMOD.

11.5.1 Protecting Photosynthesis under General Principles
of International Environmental Law

The resurgent interest of environmental protection as a component of the law of
armed conflict, is part of a wider interest in environmental protection under
national and international law in recent times. The linkage of environmental
protection and human rights came to the fore in Judge Weeramantry’s separate
opinion in Gabčíkovo-Nagymaros Project. Arguments have been made for a
human-centred recognition of a full-fledged right to the environment, and for a
long-term public policy debate in which such a virtue sits alongside the human-
centred justice and equity. Other commentators have also argued that the right to

44 The environment has a long presence in the law of armed conflict, but recent developments
have brought the environment back into explicit focus both as a ‘subject’ of protection in its own
right (ENMOD), and as a fundamental requirement of human survival and development: see, for
example, Protocol on Explosive Remnants of War (Protocol V) to the Convention on Prohibitions
or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be
Excessively Injurious or to Have Indiscriminate Effects, 28 November 2003, 2399 UNTS 100
(entered into force 12 November 2006).
45 Van der Vyver 2009.
46 Case Concerning Gabčíkovo-Nagymaros Project (Hungary v Slovakia), ICJ Reports 1997, 7,
p. 88 (Separate Opinion of Vice-President Judge Weeramantry).
48 Faunce 2012a.
a healthy environment must be recognised as *jus cogens*. Such ideas would encompass protection of the photosynthetic process.

However, mitigating the adverse impacts on the natural and artificial photosynthetic process during armed conflict is, arguably, better addressed by the law of armed conflict rather than international environmental law. The *Trail Smelter* principle limits any action taken by a state that would cause trans-boundary environmental harm. Whether this principle applies to armed conflict is uncertain, yet it is worth considering whether interfering with climate change mitigation activities occurring in any one nation as part of a global system to combat climate change could be considered a form of trans-boundary harm directed at all nations. Attacks on artificial photosynthetic energy systems could create an environmental hazard if the catalyst (e.g., cobalt nanoparticles) or if one of their outputs (i.e., methanol in ground water) proved toxic. It could also create a hazard if large-scale orbital solar reflectors were used to focus solar energy on centralised artificial photosynthesis plants, or if it produced too much atmospheric oxygen. In this context, consideration should also be given to more robust applications of the precautionary principle, as applicable under different instruments of international environmental law. This may justify or require protection of natural photosynthesis on the grounds that there is a direct or indirect threat of serious or irreversible environmental damage, even in the absence of scientific certainty as to the causal relationship, nature or extent of that damage.

### 11.5.2 Protecting Photosynthesis under General Principles of the Law of Armed Conflict

Direct protection of the photosynthetic process could be afforded by Articles 35(3) and 55 of Additional Protocol I. Article 35(3) of Additional Protocol I prohibits "methods or means of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment". This obligation applies only to military action that directly targets the environment as a means of warfare, for example, the cloud seeding efforts of the US military during the Vietnam War, but not directed at collateral damage as a consequence of conventional warfare. Article 55 of Additional Protocol I, on the other hand,

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49 Berat 1993, pp. 338–339.
50 van Laer 2010.
52 Gardam 1997, p. 89.
54 Bothe et al. 1982, pp. 345, 348.
imposes a general duty of care to protect the natural environment against widespread, long-term and severe damage. These provisions could clearly cover military attacks that permanently disable the natural photosynthetic mechanisms of ecosystems. It is less certain whether the same obligations apply to methods or means of warfare targeting artificial photosynthetic systems.

It could be argued that direct attacks on centralised artificial photosynthesis systems might be unlawful under Article 56(1) of Additional Protocol I which prohibits attacks on ‘works or installations’ that ‘may cause the release of dangerous forces and consequent severe losses among the civilian population’. Yet such systems currently do not fall in the enumerated list of protected facilities (such as nuclear power plants), and exceptions can arise ‘if it provides electric power in regular, significant and direct support of military operations and if such attack is the only feasible way to terminate such support’. There has also been a proposal to de-militarise nature reserves (which would indirectly protect natural photosynthesis) within the meaning of Article 60 of Additional Protocol I. As it currently stands, therefore, Additional Protocol I does not specifically prohibit military attacks on artificial, as opposed to natural, photosynthetic processes.

11.5.3 Protecting Photosynthesis under ENMOD Convention

The ENMOD Convention prohibits the use of hostile environmental modification techniques, which are defined as ‘any technique for changing—through the deliberate manipulation of natural processes—the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space’. ENMOD principles were also reaffirmed in the Framework Convention on Climate Change. The basic thrust of the Convention is to prohibit using the forces of the environment as weapons (i.e., causing earthquakes or tsunamis). ‘Deliberate manipulation’ is required and so collateral damage is excluded. However, the protection of natural and artificial photosynthesis may well be required under this set of norms.

The ENMOD Convention is envisaged as prohibiting hostile uses of environmental modification, such as the deforestation practiced by the US in the Vietnam conflict. For the prohibition to apply, the effect of the modification must be ‘widespread, long-lasting or severe’. The impact of a modification will be

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55 Additional Protocol I, Article 56(2)(b).
57 ENMOD Convention, Article II.
59 ENMOD Convention, Article I.
'severe' if it causes 'serious or significant disruption or harm to human life, natural and economic resources or other assets'. An environmental modification aimed at disabling distributed artificial photosynthesis facilities upon which a community depends for energy and/or food production would disrupt human life and economic resources (i.e., energy and food), and therefore is a prima facie breach of the Convention.

It has been argued that the action of the Iraqi government in draining the Mesopotamian wetlands in 1991, in an effort to destroy the livelihoods of the Shi'ite Ma'Dan minority, constituted an environmental modification of the type prohibited by the ENMOD Convention, but it would not have applied for two reasons. Firstly, the Iraqi government had not ratified the Convention and it is unclear whether its provisions had reached the status of customary international law. Secondly, the Convention applies only to conflicts between states and not to internal conflicts. These restrictions mean the limited relevance of this Convention to military attacks on photosynthetic processes.

The ENMOD Convention, although forbidding the use of environmental modification techniques in hostile circumstances, supports the use of weather modification (such as cloud seeding for rain) for peaceful purposes and, as mentioned above, global artificial photosynthesis particularly through its carbon dioxide reduction component, could fall into this category. Some techniques, such as those triggering earthquakes or causing tsunamis, discussed previously as potentially covered by the ENMOD Convention, are much more speculative than artificial photosynthesis and are far beyond the capacity of current technology. Indeed, one commentator has observed that '[s]uch techniques are not as yet a problem in warfare and their relevance to energy is not apparent'. Nonetheless, targeting artificial photosynthesis, which on some projections is set to become a ubiquitous renewable hydrogen fuel source and carbon dioxide mitigation technology incorporated in all roads, buildings and vehicles, may well be interpreted as falling within ENMOD protections due to its involvement in the deliberate manipulation of the natural processes—therefore part of the natural environment—should it become a major means of regulating oxygen and carbon dioxide levels for the benefit of the rest of the biosphere.

60 Roberts and Ginell 2000, p. 407.
61 It may well be seen as part of the customary international law rule that prohibits the use of methods or means of warfare that are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment.
63 Gudam 1997, p. 93.
11.6 Conclusion

Centralised energy systems have long been military targets. Photosynthesis has long been ‘indirectly’ targeted by the military (for example, through scorched-earth policies) as a means of denying opposing forces access to supporting food and energy. This chapter has explored the proposition that as sustainable energy solutions become more de-centralised and ‘off-grid’ they may become ‘direct’ military targets. The particular scenarios selected here for analysis in that context involve direct and indirect military attacks upon natural photosynthesis, utilising sophisticated understandings of the molecular basis of that process, and upon artificial photosynthesis.

The ultimate form of artificial photosynthesis power systems is the subject of debate and speculation (should they become commercially viable at all), but there are some elements that could set them apart from traditional power infrastructure, which are relevant to their potentially becoming military targets. Artificial photosynthesis systems are likely to operate for the purposes of both power generation and carbon sequestration, which on some projections are set to become a ubiquitous fuel source and the operation of these facilities will produce global environmental benefits. The benefits of the operation of artificial photosynthesis power facilities are likely to be enjoyed not just by the targeted country, but by the entire global community.

This chapter has argued that basic principles of international environmental law may prohibit direct military manipulation of natural or artificial photosynthesis, though the applicability of those environmental principles during warfare is questionable. It has also been argued that natural photosynthesis may be directly or indirectly targeted by military operations in ways that may breach Articles 35(3) and 55 of Additional Protocol I. Military attacks on artificial photosynthesis, on the other hand, could be seen as ‘deliberate manipulation of natural processes’ because of their eventual significance to the sustainability of the biosphere, and therefore be prohibited under the ENMOD Convention.

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