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Geosynthetics – A Sustainable Construction Material

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ABSTRACT

Geosynthetic is a broad term given to geotextile, geomembrane, geogrid, geocell etc. It's provenance in the 60's was primarily the cut of construction cost and time. Ubiquitous savings were evidenced over the years. Several decades later, a new age of sustainable construction is dawning, in preserving resource, mitigating climate change and reducing greenhouse gas (GHG) emission, the best of both worlds in cost effectiveness and sustainability. But how sustainable is with the use geosynthetics. Carbon footprint assessment has been introduced to quantify any hindsight. From resin production, to manufacturing, to shipment and from site installation, to operation, to maintenance and eventually to dismantling and disposal, equivalent CO_2 emission can be traced and calculated. This paper reviews some of the trends and studies on this emission benchmark development, and therefore the comparison of CO_2 emission between different methods of construction with geosynthetic and that of the conventional. The picture, indeed, underpins cogent discussion. It is hoped that a change of local mind set to appreciate geosynthetic, to accept its design, to review construction rule and regulation and to educate the next generation can be way forward to underline geosynthetic as a viable sustainable construction material.

From the beginning - Geotextile debut in Europe in the 60's as a man-made granular filter. The innovation took the construction industry to enjoy high efficiency, financial benefit, readily availability and predictable performance enhancement. Application exponentiated, largely the drive and espouse of textile company (Tencate, Nicolon) and chemical companies (ICI, Dupont, Amoco). Soil reinforcement geogrid, barrier geomembrane, erosion control geocell received similar zeal and the generic term 'geosynthetic' to represent this group of material was officially coined in 1977. What was not realized then was the contribution to sustainability, the avoidance of the depletion of natural resource to maintain an ecological balance for the future generation in a world we are living beyond our means. United Nation Program 2016 establishes 17 sustainable development goals (SDG), geosynthetic excels in goals 6, 9, 12, 13 & 17, preserve resources, access clean water, reduce GHG emission, control climate change, safeguard from contamination and protect the environmental. These are very macro goals pillared by environmental, economic and social considerations. This paper focuses only on the environmental impact, in terms of GHG, on using geosynthetic in construction.

Carbon footprint - In 1988, at the UN initiatives, European Commission put forward GHG policy that heralded Intergovernmental Panel on Climate Changes (IPCC) report 2014 on controlling 'GHG emission'. The term becomes the marker of sustainability used by international treaties, agreements and targets. Since over 76% of world's GHG is CO_2 (along with methane, nitrous oxide, hydrofluorocarbon, perfluorocarbon & sulphur hexafluoride), CO_2 emission was consolidated and adopted to ascertain the level of sustainability.

CO_2 emission can be presented as a quantitative measurement of GHG emission over the whole life for a specific product or service or solution or event expressed in tonnes of carbon dioxide equivalent (tCO_2e), It is derived from the total embodied energy (EE) (J/kg) consumed in each key source of the entire supply chain and operation of, in our case, a specific construction activity. EE is then converted to EC through knowledge of CO_2 emitted during generation of the energy used (oil, fossil fuel, wind, solar, nuclear, renewal etc). This associated total gas emission, embodied carbon (EC), sums up the carbon footprint of any unique construction method, solution or project. It allows comparison between different construction scenario - less emission leads to better sustainability.

Sustainability assessment - Sustainability is gauged to satisfying and balancing three sets of requirements, environmental, economic and societal/functional/equity criteria. Methods can be by means of qualitative method using colour coded chart and figure or quantitative method using rating system or sustainability metrics using EC accumulation based on a defined life cycle. EC interpretation is the simplest and most widely used in construction. Economic consideration such as financial impact and direct cost, and social equity such as resource depletion, climate change (GWP), photochemical, desertification, deforestation, ozone creation, acidification, eutrophication, toxicological effect, land competition, water use, air pollution, modification of ecosystem, even road congestion, noise & air pollution and aesthetics are much wider scope beyond construction activities. Economic and social issues are not adduced here.

Life cycle assessment (LCA) – LCA is a method to determine EC emission. There are several boundary conditions, acquisition of raw material and production processes of a construction material, eg geosynthetic (cradle to gate CTG), transportation of material to site (cradle to site CTS), use of the material for construction (cradle to construction CTC) and operation, maintenance and final dismantling, disposal and recycling at the end of the life (cradle to grave CTGr). The method generally takes reference to ISO 14040, 44 and 49, environmental management LCA principles; PAS 2050:2011 UK carbon footprint standard, EU international Life cycle data handbook, BPX 30-323 French footprint guideline and USA EPA life cycle assessment, principle and practice; or other countries' specific requirement. These are well document, transparent, repeatable guideline to conduct and report LCA.

To establish comparative life cycle analysis, same scope of use, technology and functions are essential. Boundary condition and scope of emission analysis, solution, or design in which the basis for comparison must be defined, inventory of material must be quantitated, each source of material must be determined, transportation, installation and construction activities must be recorded, end of life duty are to be known and finally the accumulated EC can be calculated and compared. A low carbon alternative can then be concluded. Since the relative reduction is often sought, some common denominations, activities and material to both solutions are balanced out, such exercise can be excluded. Geographic location, culture, local practice, resources differ from place to place, constant evolution to encompass different approach, priority and stakeholder's interest can compound any analysis. As such, every LCA has its unique characteristics, hence its footprint or "the carbon footprint".

The cumulated energy demand (CED) is first calculated by iterate approach, summing up the actual energy consumed of all items in the supply chain for each cycle; excavation of raw material (soil, gravel, clay, ore, crude oil, resin); transportation of raw material to site or factory; production of primary product (cement, lime, iron ore, polymer); transportation of primary product to manufacturer or contractor; manufacturing of product (concrete, steel, geosynthetics); transportation of product to site; integration of the product at site; realization of installation and construction; using of product and maintenance until end of life; dismantling, re-using, recyclingmethod, energy recovery and ultimate waste disposal. CED can then be converted to EC. Table 1 expatiates the framework of LCA, mapping out the typical supply chain, EC data sourcing, material inventory and calculation of total EC emission of any particular construction method, solution or project.

There are open sources of international EC value database for calcualtion (Inventory of carbon & energy, Harmmond & Jones at Bath University (2011); European life cycle analysis database 'Ecoinvent v3.3' (2016); International reference life cycle handbook (ILCD 2010); Germany Institute FFR in house calculator from manufacturers; US EPA, inventory of US greenhouse gas emission and sinks (2008); Chinese life cycle database 2013. However, none of these cover geosynthetic product as yet, only that of generic polymer type of which the geosynthetic is made from or that provided by some manufacturers can now be used for analysis.

CTG is relatively straight forward because of the abundance of EC data, CTS is geographical location dependent and has dramatic variations, CTC adds on the reliance of local experience, site record and staunch construction data. CTGr is complicated by the fact that civil engineering works tend to have little energy consumption in operation and maintenance (except disaster repair) and indeed many structures have not come to an end of life, let alone dismantling and disposal. Therefore, most of the geosynthetic LCA studies focus on CTG, CTS and CTC.

Typical Framework of Life Cycle Assessment	Parameter	Embodied CO_2 Emission
Comparative CO_2 study purpose & scope	Project information	
LCA boundary conditions	Criteria identification	
Comparable solution & designs scheme	Solution & design details	
Preparation and Setting up		
Raw material extraction (i.e. iron ore, aggregate, crude oil)	Material inventory quantitates, EC data soruce	Calculate Embodied
Transport raw material to factory (i.e. method, load and fuel)	Distances & fuel	Conversion to carbon emission
Primary production (i.e. cement, resin, concrete, steel)	Material inventory quantitates, EC data soruce	Calculate Embodied
Transport primary product to manufacturing (i.e. method, load and fuel)	Distances & fuel	Conversion to carbon emission
Product production (i.e. concrete, steel , geosynthetics)	Material inventory quantitates, EC data soruce	Calculate Embodied
Cradle to Gate (CTG)		∑ **Embodied CO_2 Emission**
Material (i.e. soil, stone, concrete steel, geosynthetics)	Material inventory quantitates, EC data soruce	Calculate Embodied
Transport of material to site (i.e. method, load and fuel)	Distances & fuel	Conversion to carbon emission
Cradle to Site (CTS)		∑ **Embodied CO_2 Emission**
Plant & equipment (i.e. installation, construction, material integration)	Distances & fuel	Conversion to carbon emission
Cradle to End of Construction (CTC)		∑ **Embodied CO_2 Emission**
Plant & equipment i.e. (use of material, operation, maintenance)	Distances & fuel	Conversion to carbon emission
End of life (i.e. demolish, dismantling, disposal)	Distances & fuel	Conversion to carbon emission
Cradle to Grave (CTGr)		∑ **Embodied CO_2 Emission**
	Total Accumulated Embodied CO_2 Emission	

Table 1 - Framework of Life Cycle Assessment (LCA)

Beauty of using geosynthetic - For many years, economical advantage of construction incorporating geosynthetics are acknowledged. Some obvious countenances are pinpointed on more efficient use of natural resources, improvement of performance of scarce material, less excavation and quarrying, less use of concrete and steel, less transportation and haulage, less manoeuvring on site and less wastage, streamlining construction activities, allowing the use of lower grade granular material at the same time. Indeed, geosynthetics shred granular use, optimise difficult design, extend service life, minimize land disturbance and erosion, enhancing resilience to coastal protection, safeguard marine engineering destruction and generate green power. Innovations put in practice are evolved time and again.

Classic examples are geogrid in reinforced fill construction, geomembrane in containment barrier, geocomposite in drainage and harvest biogas, geotextile in road paving stability. Several manufacturers claim palatable merit of geosynthetic - 300-500 mm stone layer can be replaced by a 4-25 mm drainage geocomposite, one truck load stabilization geogrid saves 200 truck load of aggregate, 150 truck of clay is equivalent to 1 truck of GCL and 1 pallet of geosynthetic cementitious composite mat (GCCM) can be used when 6 trucks of shotcrete are needed.

LCA Research and Case History – With these beauties, a great many studies on comparative LCA involving the use of geosynthetic have been published. Earlier reports are from WRAP (table 2) and EAGM (table 3). Together with this prominent research, a collection of LCA from geosynthetic manufacturers (table 4) and that from the academics (table 5) are enumerated for reference.

WRAP (Waste & Resources Action Programme, UK) - WRAP is a published geosystem report "Sustainable geosystems in civil engineering applications" authored by 16 UK organizations (one third was involved with geosynthetic) in February 2010. It showcases the potential in EC reduction, adding element of cost, time, and material wastage savings through detailed calculation of six cases of civil engineering projects, comparing the carbon emission in each case with the use of geosynthetic against that of the conventional. Unambiguous conclusion was drawn to the significance of CO_2 reduction (from 31% to 87%). See table 2.

Construction and Design		Carbon Emission (ton CO_2e)		Reduction
Enbankment bund - 9.5 ht x 350 m	CTC	Gabion system 143.17	Reinforced soil 19.21	87%
Bridge approach 1V:2H - 40,000 m^3 fill	CTC	Gravel fill 454.12	Geogrid with cohesive soil 314.02	31%
Rebuilding collapsed retaining wall - 20 m	CTC	Reinforced concrete 32.26	Geogrid crib wall 9.55	70%
Interlock steel pile wall - 112 ton pile	CTC	Sheet pile wall 393.42	Steel strip RE precast wall 72.78	82%
Retaining concrete wall - 230 m^3 reused fill	CTC	Reinforced concrete 96.95	Modular block wall 42.46	56%
Retaining wall drainage layer - 2.5 km	CTC	Hollow block drainage 171.93	Geocomposite 29.01	83%

Table 2 - Waste & Resource Action Program (WRAP) Geosystem Report February 2010 [5]

EAGM - European Association of Geosynthetic Manufacturer (EAGM) did a study titled "comparative life cycle assessment of geosynthetic versus conventional construction material" between 2009-2011 to promote the knowledge of high quality geosynthetic and to underline the benefits when applying these products. Four exemplary models of common and frequent construction applications where geosynthetic and conventional solutions with technically equivalent function were chosen. Apart from carbon footprint, eight economic and social impact indicators were assessed, adhered to ISO 14040 and 14044. The results were shown as CTGr but the report centered on CTC when operation and maintenance were omitted citing too little impact. Geosynthetic does offer "advancing sustainability". A subsequent critical review was performed by three independent experts in 2018. The report was re-presented in 2019 and the reduction of carbon emission (from 11% to 90%) concluded in 2011 remains consistent, sound, and valid. See table 3.

Construction and Design		Carbon Emission (Kg CO_2e/m2)		Reduction
Foundation & subgrade filter separation layer	CTGr	Gravel base 7.80	Geotextile base 0.81	90%
Road foundation on weak soil 1 km x 12 m width	CTGr	Conventional fill base 730.00	Geogrid base 650.00	11%
		Cement/lime base 950.00	Geosynthetics base 650.00	32%
Landfill drainage system	CTGr	Gravel base drainage 10.90	Geocomposite 3.60	67%
Retaining wall 3 m height	CTGr	Reinfoced concrete wall 1300.00	Geogrid reinforced wall 200.00	85%

Table 3 - Comparative Life Cycle Assessment EAGM Report 2019 [1]

Research around the world – A wide spectrum of similar comparative studies covering different type of construction method and solution, protean design with a variety of geosynthetic are described in case history literatures from geosynthetic manufacturers (table 4) and journalized by savants and practitioners (table 5). Substantial carbon reductions are reported across the board.

	Construction and Design		Carbon Emission (ton CO_2e)		Reduction
ACE Geosynthetics Taiwan 2013	Road rehabiliation 150 m length 10 m height	CTS	Retaining wall 3167.00	Reinforced soil slope 670.00	79%
Huesker Germany 2015	Lining protection trial 10,000m2	CTC	Clay ballast liner 506.30	Geosynthetic mattress 20.70	96%
Maccaferri Italy case study 2014	River revetment	CTC	Gravity wall 54.00	Gabion 18.00	67%
	Gavity wall	CTC	large stone riprap 160.00	Reno mattress 80.00	50%
Maccaferri Italy techncial note	Retaining structure 8 m ht 10 m	CTC	Concrete wall 52.00	Gabion wall 7.50	86%
	River bank protection 5,400 m^2	CTC	Riprap 160.00	Reno mattress 80.00	50%
Tensar USA Research 2016	Optimized pavement design 1 km x 20 m	CTC	Primary pavement 4977.00	Geogrid pavement 3822.00	23%
Pietrucha Poland study 2019	Sheet pile 1 km 5 m depth	CTC	Steel sheet pile 1830.00	PVC sheet pile 200.00	89%
Solmax Canada techncial notes	Impermeable lining, 4,047 m^2	CTC	Clay/HDPE/granular 250.00	GCL/HDPE/geocomposite 68.00	73%
ABG UK Production	Drainage core with recycled HDPE	CTG	100% virgin resin 2.13	80% recycled 1.24	42%
ABG UK technical note	Landfill slope drainage 22,500 m^2	CTC	Gravel with geotexitle 600.00	Geocomposite 318.00	47%
ABG UK technical note	Retaining Wall drainage 55 m2	CTG	Hollow drainage block 1.79	Geocomposite 0.15	92%
		CTG	No fine concrete 4.31	Geocomposite 0.15	97%
Concrete Canvas UK techncial note	Slope erosion protection 100 m2	CTG	150 mm concrete 3.60	8 mm GCCM 1.61	55%

Table 4 - Life Cycle Assessment from Manufacturers' literature

	Construction and Design		Carbon Emission CO_2		Unit	Reduction
Herteen	Retaining Structure 150 m x 5.5 m ht	CTC	Retaining wall 542.00	Green slope 101.00	ton	81%
	Road improvement	CTC	Lime /cement milling 1325.00	Geogrid 49.00	ton	96%
Viktor Toth 2018 [21]	Terrace wall, 6 m height		Retaining wall	Face panel		
	Extract raw material		75.00	10.00	kg/m	87%
	Import material and construction		33.00	16.80	kg/m	49%
	Operation, removal and disposal		9.80	6.00	kg/m	39%
		CTGr	117.80	32.80	kg/m	72%
	Terrace wall, 6 m height		Retaining wall	RE steep slope		
	Extract raw material		75.00	3.50	kg/m	95%
	Import material and construction		33.00	16.90	kg/m	49%
	Operation, removal and disposal		9.80	5.00	kg/m	49%
		CTGr	117.80	25.40	kg/m	78%
Geosyntheitcs	Landfill capping barrier 9,572 m^2	CTC	1,000 mm clay 111.37	Geomembrane / geotextile 32.20	ton	71%
ICE Publishing 2016 [2]	Hypothetical Retaining wall 15 m ht	CTC	Gravity wall 28.00	Geogrid MSEW 3.00	t/m	89%
		CTC	Gravity wall 28.00	Steel strip MSEW 4.00	t/m	86%

Table 5 - Life Cycle Assessment Research Summary

24th Geosynthetics Research Institute Conference March 2011 [12]	Levee after Katrina, New Orleans	CTS	Compact concrete 0.53	Turf reinforced mat 0.09	t/sy	84%
		CTS	Articulating concrete block 0.59	Turf reinforced mat 0.09	t/sy	85%
	Erosion control, California 8,890 m^2	CTC	Concrete swale 246990.00	RECP channel 75622.00	MJ	69%
	Flood control dyke, Taiwan, 961 m	CTC	Concrete Slab 704.00	Erosion mat 235.20	ton	67%
	Stormwater retention 10,000 m^3	CTG	Corrugated steel pipe 571.23	Plaster Modular system 29.34	ton	95%
		CTG	Corrugated steel pipe 571.23	Corrugated plastic pipe 186.17	ton	67%
		CTG	Corrugated steel pipe 571.23	Geostorage 25.47	ton	96%
	Containment berm, 40 ft height	CTS	Unreinforced berm 3H:1V 200.30	MSE berm 0.5H/1V 133.90	kg/ft2	33%
	Hypothetical landfill bottom lining	CTS	0.6m CCL 165.00	GCL 122.00	t/ha	26%
	California Landfill closure	CTC	Soil /geomembrane 652.40	Exposed geomembrane cover artifical grass 132.20	t/ha	80%
Geosynthetic Institute white paper 41 2019 [17]	1,160 kN working platform	CTS	Conventional gravel 16.68	Polyester geotextile 9.53	kg/m2	43%
Geosynthetics Institute white paper 44 2020 [19]	Unpaved road 800 m x 4 m	CTG	Gravel strength sub-base 94.00	Woven geotextile 25.00	ton	73%
	Reflective crack prevention 100 m x 9 m road	CTG	Bituminous overlay 18.60	Paving geotextile 10.90	ton	41%
	Paved road 1.6 km x 9 m	CTG	Aggregate Asphalt 536.00	Tri-axial geogrid 396.00	ton	26%
	3H:1V slope 10 m long 5 m section	CTG	460 mm Rip rap 4360.00	Turf reinforcement mat 356.00	ton	92%
MDPI Journal Sustainability 2021 [18]	Dyke, Germany, external sealing	CTC	Clay 122.30	GCL 70.80	kg/m^2	42%
		CTG	9.90	4.00	kg/m^2	60%
Master thesis University of Toledo 2015 [23]	Hypothetical retaining wall 35 ft height	CTG	Gravity retaining wall 1680.00	MSEW 620.00	kg/ft^2	63%
		CTG	Gravity retaining wall 1680.00	Geotextile wrap around wall 100.00	kg/ft^2	94%
		CTG	Gravity retaining wall 1680.00	Gabion wall 100.00	kg/ft^2	94%
Geoamerica 2016 Proceeding [14]	Bridge Abutment 4.7 m ht x 11.7 m	CTG	Geosynthetic MSPW 49.84	Geosynthetic reinfoced block 30.80	ton	38%
Handbook of Geosynthetic Engineering 2012 Chapter 18 [24]	Retaining wall 4.6 m ht x 131 m	CTG	Gravity wall 420.00	MSEW 99.00	ton	76%
	Landfill drainage	CTC	Mineral drain 192.00	Geocomposite 137.00	MJ	29%
Geotextile from Design to Applications 2016 Chapter 26 [10]	Filter layer	CTG	100 mm sand 1.02	Non woven geotextile 1.18	kg/m^2	-16%
	50 km away	CTS	1.78	1.18	kg/m^2	34%
	100 km away	CTS	2.56	1.18	kg/m^2	54%
	Working platform	CTS	1.2 m aggregate 16.68	0.6 m aggregate/geotextile 9.53	kg/m^2	43%
	Landfill capping	CTC	1,000 mm cohesive soil 47.22	1.0 mm LLDPE / geotextile 32.03	t/ha	32%
GeoAmerica 2020 Proceeding [29]	Waterproofing 10,000 m^2	CTG	Compacted clay 109.59	1.5 mm geomembrane 30.84	ton	72%
GeoAmerica 2020 Proceeding [28]	Primary leachate collection system 6,000 m^2	CTG	800 mm granular layer 6.40	7 mm geocomposite 4.60	ton	28%

Table 5 - Life Cycle Assessment Research Summary

In all these quests, the outcome of low carbon footprint is no surprise, with remarkable saving of up to 97% in certain application. Table 6 wraps up the carbon reduction of all these forty-eight LCA analysis. Typical constructions are categorized into retaining structure, ground stabilization, containment, erosion control and drainage. In figure 1, comparative construction schematics are put side by side with the corresponding reduction percentage. The ceiling of an upside (80 - 97%) is to be proud of, even the bottom line (28 - 50%) cannot be slighted.

Construction and Design	Cases	CO_2 Reduction Ceiling	CO_2 Reduction Bottom line
Retaining structure vs reinforced structure	15	94%	33%
Granular formation vs geotextile stabilization	7	96%	23%
Containment barrier vs geomembrane and Geosynthetic Clay Liner GCL	7	80%	26%
Embankment structure vs erosion geosynthetic	9	96%	50%
Granular drainage vs geocomposite	9	97%	28%
Recycled polymer vs virgin material	1	55%	-

Table 6 - Summary of Carbon Emission Reduction

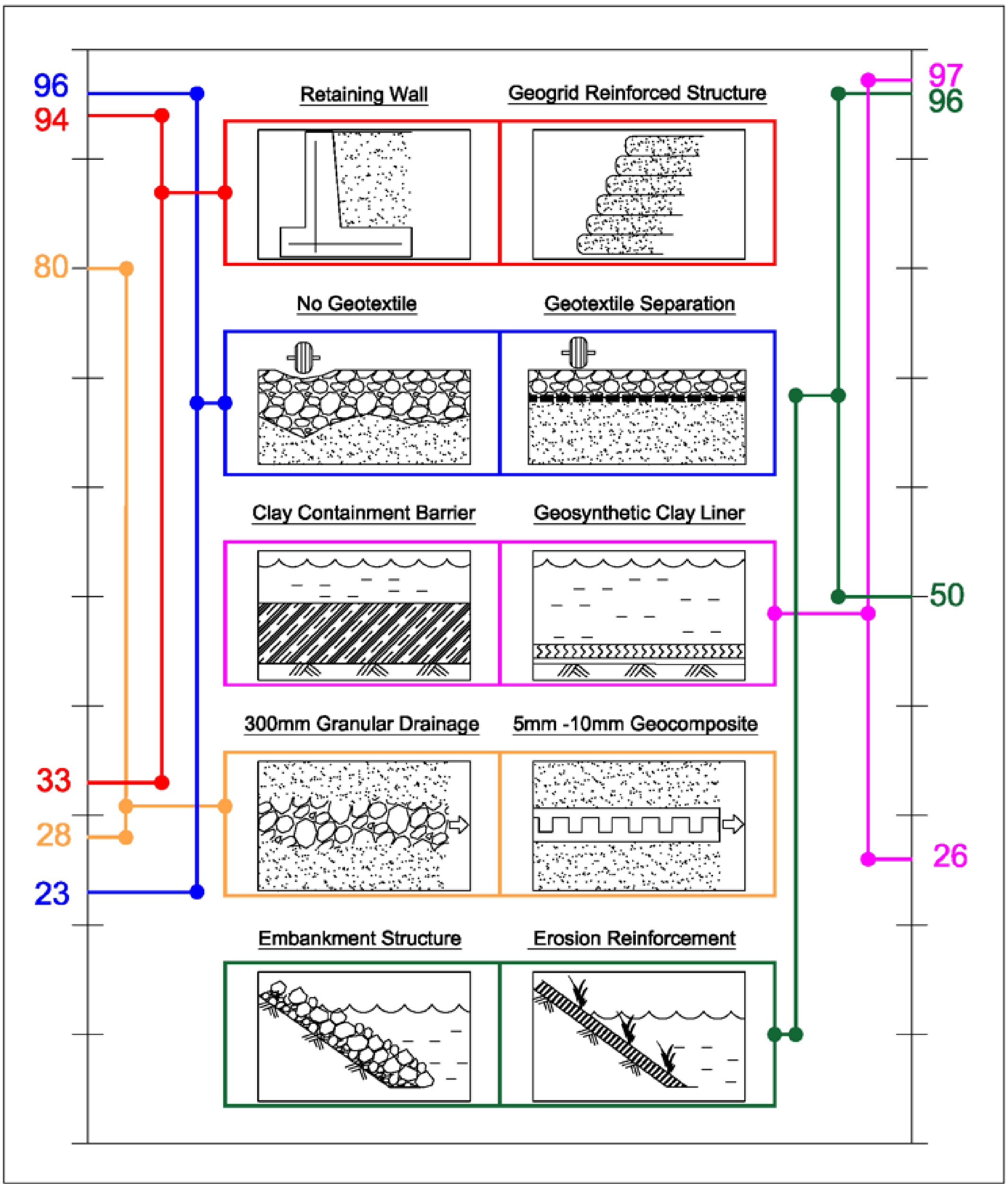

Fig 1. Percent of CO_2 Emission Reduction - Geosynthetic VS Conventional

Reliable embodied carbon database – LCA methodologies employed are relatively consistent, despite the fact that geosynthetic EC data base is not available. Dixon [4] coordinated with manufacturers in 2015 to collect raw material source, logistic data and energy consumption in geotextile and geogrid production process to come up with specific CO_2 emission. The actual measured energy is then converted to CO_2 by UK greenhouse gas reporting conversion factors (DEFRA 2013). First-hand calculation of non-woven PP geotextile give an EC value of 2.28 – 2.42 tCO2e/t (EC of PP film grade resin is 3.43 – 4.49 from ICE polymer data base), that of extruded PP geogrid is 2.97 tCo2e/t and PET woven geogrid is 2.36 tCO2e/t (EC of PET granule is 2.70–2.90 from EcoInvent polymer data base). Since current LCA studies rely mostly on open-source polymer data base which are considerably higher than that calculated from Dixon, EC is therefore generally overestimated, or current LCA tends to be conservative. There is a strong motivation to apprehend a more realistic comprehensive geosynthetic data base.

Recycling dilemma – Used of regrind and offcut material is an option to reduce carbon emission. In Europe, CE marking Declaration of Performance under the EN harmonized standards for geosynthetic allows manufacturers to declare a service life of 5 years with inclusion of any post-industrial or post-consumer polymer (PIM or PCM) and only for non-reinforcing functions. As most manufacturers could not guarantee a sufficient consistency of supplying recycled to ensure reliable durability prediction, resetting these rules will be long and hard. In any case, Geofabric in Australia has made non-woven paving fabrics from recycled plastic bottle in May 2020. Kaytech in South Africa did not use virgin resin for geotextile since early 2000s. In Brazil, run off drain uses compressed plastic bottle encased in geotextile. Rework, regrind and multi processed polymer is very well manipulated in China to compensate price concession. In USA, off spec material is at steep discount. However discordant, manufacturing geosynthetic, by and large polymer chemistry, stimulates and encourages recycle and reuse. The ambivalence appears to be identifying the balance and compromise when entrenched quality assurance associated with virgin resin and sustainability supported by recycling are treasured at the same time.

International Geosynthetics Society (IGS) enthusiasm- the prestigious association shares the UN's SDGs blueprint and is committed with a sustainability mission which will engage members, suppliers and stakeholders to improve, report, disclose sustainability performance through webinar, conference and lecture. A special committee kick started a task force in October 2019 spearheading the understanding and adoption of geosynthetic as a key component in creating more sustainable actions, such as promoting the swap of geosynthetics solution for less sustainable construction techniques, reintroducing production waste to feed stock, designing application with better performance and perfecting carbon emission data base. These are positive directives.

Manufacturer dedication - Geosynthetic manufacture's impetus of rolling out green measures to join force in corporate social responsibility (CSR) and environment, social & governance (ESG) program, and to capitalize on sustainability. In the spring 2021 IGS survey, most prominent manufacturers have environmental policy or are planning one. Many are carving out ways to enhance product and performance, to formulate requirement to upstream supplier, to provide more unbiased EC database regardless of commercial confidentiality and to cap production energy.

Some examples: Solmax's heat recovery realizes 90% natural cost from 2019 by pit thermal energy storages; TRI's foul water management slashes water use by 70%; RE-Gen Enterprise supplies regrind from used containment liner; Maccaferri's new steel coating extends service life, Agru's closeturf integrates impermeable high friction barrier with artificial turf; Tencate glacier's geotextile slows snow melting; Concrete Canvas's GCCM replaces permanent shotcrete; ABG's geocomposite retains soil moisture on roof garden; drainage cell improves storm drain storage capability; geofoam lightweight backfill substitutes import fill; electrokinetic speeds up stability equilibrium; geocell improves resilience of coastal protection and the list goes on. Outrageous ideas not too long ago are now on stream. Thanks to the persistence of manufacturers and the understanding of engineers.

Carbon Credit - Following the Kyoto Protocol, carbon credit investment market has been established to mitigate the environmental crisis. A polluter (organization that consumes energy) can buy carbon credit to reduce their carbon footprint at a price and gain permission to generate CO_2 from those who have excess credit. This offset reconciles the continuous emission escalation. Construction industry is welcome to participate in this ‘cap and trade’ charter.

Peroration - Geosynthetics does broadened sustainable construction and provide a means to achieve long term targeted carbon emission commitment. LCA is justifiable to quantify the potential. But such analysis is sometimes a subjective interpretation and has shortcomings. With the absence of actual EC of geosynthetic and therefore the underestimation of reduction, it is discernible that any CO_2 emission reduction may not be an absolute representation. Nevertheless, reports of flying colour from most studies are continuously filed. With the recyclers’ incentive, IGS’s enthusiasm, geosynthetic manufacturers’ persistence and carbon credit market players’ interest, LCA can become a firm basis to advance geosynthetic application. There is unprecedented worldwide sustainability commitment, it is hoped that geosynthetic can play a heavier role.

Closer to home, the government leads the initiative to look at low carbon construction. The Construction Industry Council (CIC) put focus on sustainability in 2007 supporting HK climate change action plan 2030+, launched the CIC carbon labelling scheme on intensive construction material in 2013 and devised a life cycle carbon assessment tool in 2019, in line with the international approach. This refers primarily to building construction since consumption of energy with running building and human activities are far more significant. The geosynthetic community craves to see that their product would find its position, however trifling, in construction sustainability.

Climate change is sadly depicted as anthropogenic. Stronger awareness of reducing carbon emission may stimulate moral thinking to bring about sustainable construction. Transforming the mind set of placing more attention to accepting solution with geosynthetic is sought. The defiance becomes the drive of having an open mind to step aside from traditional, conformable and comfortable design, to make more adaptation to integrate geosynthetic into construction design, rule, regulation, code of practice and shrewd legislation. Indeed, the status quo seems to have remained unchanged; if something has not been used here, do not use it.

Geosynthetic is not novel and untested, as Neil Dixon professed in Geoamerica 2016 - “geosynthetic is framed as a forever new technology”. It is not. Perhaps geosynthetic is too small an item in most construction, perhaps product knowledge has not been popularised, perhaps our education curriculum has minimal coverage. Early training can be brought forward to show the rope to the younger generation. Decarbonising the world is likely to toil for donkey’s year, only achievable in the coming generations, in the meantime, every minute effort counts, slather geosynthetic in construction will hopefully step up the momentum.

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