World Currencies for Sustainability

by
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Abstract

The 2007-9 global financial crisis, the post-2009 Eurozone debt crisis, and growing inequality are reasons to critique the world financial system. More disconcerting are scientific findings that civilisation's impacts on the environment are approaching 'planetary boundaries' (Steffen et al., 2015) such as catastrophic climate change and ocean acidification. This paper presents a proposal for *Complementary Currencies for Climate Change* (4C) and it's associated mitigation policy, called *Global 4C Mitigation* (G4CM), with the specific aim of achieving strong mitigation of climate change and improved economic conditions (Chen & Cloud, 2014).

4C is a market-and-monetary instrument that will complement the international financial architecture to help correct the existing market failure in environmental externalities associated with greenhouse gases (Stern, 2007). The *unit of account* of 4C is 100 kg CO2-e verifiably mitigated, and this unit of account is unique in terms of official money because it is based on services rather than commodities or fiat banking. 4C issuance will be administratively coupled to mitigation services, and 4C issuance will be delivered globally as proportional subsidies for the de-carbonisation of industrial and power installations, and as proportional rewards for carbon sequestration. We call this incentive mechanism *Globalised Payments for Ecosystem Services* (GPES) and it will be implemented under the *Beneficiary Pays Principle* (BPP).

The G4CM policy prescribes multi-decade 4C floor price schedules. To establish these floor prices, an international monetary protocol will be used to transfer purchasing power from a comprehensive basket of fiat currencies into 4C. This monetary approach will create a concomitant rate of inflation in the fiat basket, and it is hypothesised that this cost spreading will minimise political delay over the long run. Co-benefits will include new currencies for international trade, price signals that complement carbon taxes, stimulus for sustainable projects and employment, ecosystem protection, and improved social cohesion.

The proposed 4C world currency is a new type of official money that creates a price benchmark for climate stability. We give 4C a new monetary classification: the *World Service Currency* (WSC). The 4C world service currency is advocated on the basis that it can mitigate greenhouse gas emissions to the maximum amount using market forces and a new political pathway. Nations are invited to participate in a 4C system for mutual protection by ceding some fiscal sovereignty and monetary autonomy to the G4CM protocol. The political pathway to an agreement may begin with field trials using digital currencies, followed by contingency planning and negotiations.

Keywords: World Currency, Monetary Policy, Mitigation, Climate Change, Sustainability, Market, Economics

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1. Introduction

1.1 Climate Change

The Intergovernmental Panel on Climate Change (IPCC) has firmly established that humanity is having a significant influence on the climate system (IPCC, 2014). Based on a business-as-usual scenario (RCP8.5) for greenhouse gas (GHG) emissions, the enhanced greenhouse effect could result in average surface warming of between 3.7°C to 4.8°C by the year 2100 (above the 1850-1900 average). There is general agreement amongst leading scientists (e.g. Hansen et al., 2013) that this level of warming would be extremely dangerous and must be avoided because:

"*The foundations of our societies, including food security, infrastructure, ecosystem integrity and human health, would be in jeopardy, impacting most immediately the poor and vulnerable.*" (Stern et al., 2015)

Global warming similar to RCP8.5 would lock-in additional warming for a few centuries beyond 2100 (Wasdell, 2011) and could bring about mass extinction and the collapse of civilisation (Kolbert, 2014). Disquieting reports about future climate change are common in the natural sciences, whereas economic policies tend to be more sanguine. The trend in both camps is towards a more sobering interpretation (e.g. Stern, 2013), including new assessments of statistical risk (Caia et al., 2015) and potential climate feedbacks that portend abrupt climate change (NRC, 2013). Important studies relate to: (i) political delay over mitigation policies (Rogelj et al., 2013); (ii) potential changes in the Arctic that relate albedo feedbacks, including sea ice melt, methane release (AMEG, 2014), permafrost thaw, and phytoplankton blooms (Park et al., 2015); (iii) upward revisions to climate sensitivity due to atmospheric circulation (Sherwood, Bony & Dufresne, 2014; Bony et al., 2015); (iv) vegetative carbon cycle change in the Amazon (Brienen et al., 2015); (v) glacial flow in Antarctica and Greenland (Hansen et al., 2013); (vi) oceanic thermal cycles (Roberts et al., 2015); and (vii) a bias for economic growth beyond 2050 with attendant CO_2 emissions (Randers, 2012; Garrett, 2012a)

The politics of climate change involves actors who seek sufficient political power to implement carbon policies within the government apparatus, but political power requires significant social-capital. Self-interest, on the other hand, is an *intensive* property of individuals (e.g. Andreoni et al., 2003). Individuals and firms may be reluctant to accept new carbon taxes if they perceive a loss of self-interest. Inaction and delay may be the default option of many individuals and firms, and so the political narrative diverges from the climate science and dissonance is created in the broader narrative, as illustrated with this quote from Anderson & Bows (2012):

"*Put bluntly, while the rhetoric of policy is to reduce emissions in line with avoiding dangerous climate change, most policy advice is to accept a high probability of extremely dangerous climate change rather than propose radical and immediate emission reductions.*"

1.2 Money

The history of money begins in ancient Mesopotamia roughly 5000 years ago, with the oldest surviving records of debits and credits (Ferguson, 2009). Money is therefore an ancient social tool, and it is also an essential nation building institution. Despite the antiquity of money, there are just three major types of money commonly used by governments for nation building, namely: commodity money, representative money, and fiat.

Commodity money is a quantity of commodity (e.g. gold or silver), representative money is a claim on a commodity (e.g. gold backed banknotes), and fiat is a currency with a unit of account declared by its issuing authority (e.g. the Euro). There are physical limits to the amount of commodity money that can be issued, and the supply of representative money 'should' be limited by the availability of commodities through an administrative system. The value of commodity money is clearly linked to commodities, however the market value of all money ultimately depends on supply-demand created by an economy.

Fiat money can have virtually no intrinsic value, as is often the case, but it can have reliable purchasing power because it is given legal tender status that requires it be used to pay taxes and to trade. The supply of fiat is purely administrative, because the base issuance of new fiat occurs when central banks purchase financial assets or lend to financial institutions. Commercial banks are allowed to expand the fiat supply in a process called *fractional reserve banking* which involves issuing new fiat as credit (i.e. interest bearing loans). Of the three major types of money mentioned, fiat can have the most expansive money supply because it is not physically limited. Today most fiat money exists in digital form. In the U.K. in 2010, for example, only about 2% of money existed as banknotes and coins (Lipsey and Chrystal, 2011).

There are also many forms of non-official money, including alternative and community currencies, however for reasons of brevity we only discuss common digital currencies[2]. Digital currencies (i.e. crypto-currencies) are a relatively new type of money created administratively with the medium-of-exchange being provided by digital algorithms on computer networks. Digital currency technologies have the potential to be used to administer digital representative currencies and digital fiat, however most digital currencies are currently developed outside of the state apparatus and have no official backing. For this

[2] The commonly traded digital currencies are listed here: http://coinmarketcap.com/

reason the market value of most digital currencies is a reflection of social preference and market sentiment for those currencies.

Digital currencies enable financial transactions with an assurance of accounting accuracy and independence from central authorities because of their automated administration. The absence of trust relationships is fundamental to the technology and this is provided by a decentralised software architecture and encryption (Nakamoto, 2009). Digital currencies also offer accountability with public ledgers, and the option to limit the currency supply within algorithms or computational work limits. The technology also offers new efficiencies for e-commerce with low transaction costs and scope to include programmable digital contracts and encoded data for commerce and social networking (Etheruem, 2015).

1.3 World Currency

By one definition, a world currency is a currency that is transacted internationally and not limited by borders. Proposals for world currencies are varied, and the spectrum of ideas could have practical 'end points'. One end point is the idea of an official 'single global currency' that would replace pure-floating and semi-fixed exchange rate systems. The other end point is a financial approach that would create a derivative basket of weighted currencies for use as a stable reference currency (i.e. within a floating exchange rate system).

A notable example of a world commodity currency is the 'silver dollar' that was widely used for more than two centuries (17th to mid-19th centuries). National currencies based on gold standards were used for international trade during most of the 19th century and until WWI. World currency proposals in the post-WWII era typically express a desire for price stability, a 'level playing field', and alternatives to national reserve currencies because of the Triffen Dilemma. The Triffen Dilemma (after Robert Triffin) states that there can be a conflict of interest between domestic and international objectives for countries whose currencies serve as global reserve currencies. In anticipation of such problems, the economist John Maynard Keynes proposed a *supranational unit of account* called 'Bancor' at the Bretton Woods Conference in 1944. Bancor is not a world currency proposal, but rather it would have been used to track and clear international flows of wealth and provide incentives for nations to avoid excessive trade deficits and surpluses.

The Bretton Woods Conference in 1944 established the U.S. dollar as the world's gold-backed reserve currency, and it also established the International Monetary Fund (IMF) and the World Bank. In 1969 the IMF created Special Drawing Rights (SDR) to support the Bretton Woods fixed exchange rate system. The SDR is an *international reserve asset* (not a currency) and was created to supplement its members' currency reserves. After the Nixon shock in 1971 the gold standard was abandoned, the Bretton Woods system collapsed, and the major currencies shifted to a floating exchange rate system. In the wake of the 2007-9 global financial crisis a UN panel suggested that a new global reserve currency could be established (IMF, 2010), however the idea was not politically feasible at the time and the US dollar continued as the dominant reserve currency.

1.4 Power-to-Money Ratio

When the whole of civilisation is considered as a single physical 'system', in terms of mass, energy and financial balances, it is possible to infer the average historical relationship between (i) global economic wealth, (ii) global energy supply, and (iii) global greenhouse gas

(GHG) emissions. Data on these parameters were analysed by Garret (2012) within the framework of a thermodynamic model that treats the global economy as a single homogeneous system. Garrett's (2012) model shows that these parameters should be correlated because of thermodynamic constraints. Garrett's (2012) analysis of the historical data showed that the global economy has a stable power-to-money ratio of 9.7±0.3 mW per US dollar (inflation adjusted to 1990). This correlation is steady over recorded history even though the unit account of money was *not* denominated in units of power. Therefore the power-to-money ratio is an intensive characteristic of civilisation within its environment.

2. World Currency for Climate Change Mitigation

2.1 Power-to-Money Pivot

The inflation adjusted power-to-money ratio is relevant to civilisation's capacity for decarbonisation because it is the average quantity of power supplied for each unit of economic utility. A fundamentally new approach to decarbonisation (and to internalise the environmental costs) is to use the ratio as a 'pivot point' for decarbonising the economy. The current proposal is to create a new currency and a socio-economic agreement that gives actors in the economy the option to increase the currency supply by providing mitigation services (i.e. as an alternative to fractional reserve banking). Discipline for decarbonisation can be established with monetary rules that give the new currency a *unit of account* defined by a mass of GHG mitigated. The rate of new currency supply can be amplified with a policy that increases the currency's exchange rate and shifts the supply-demand equilibrium in favour of greater mitigation. If the exchange rate can be leveraged higher, mitigation will improve and the economy can be decarbonised. The economic theory and principles of the proposal, and its relationship to carbon taxes, are presented below.

2.2 Global 4C Proposal

This proposal for a world currency is specifically aimed at mitigating greenhouse gas (GHG) emissions and promoting long run sustainability. The currency instrument is called *Complementary Currencies for Climate Change* (4C), and the name given to the entire policy is *Global 4C Mitigation* (G4CM) (Chen & Cloud, 2014). The unit of account of 4C[3] is 100 kg CO_2-e verifiably mitigated, and hence 4C will be issued as proportional subsidies/rewards to enterprises for mitigating/sequestering GHG emissions. G4CM involves unorthodox monetary policy, a market-and-monetary framework, and new principles for market economics. The G4CM proposal is summarised in Table 1.

To avoid political delay with the implementation of G4CM, the policy should not introduce any new taxes to finance 4C. The aim of the G4CM protocol (Table 1) is to transfer purchasing power from a large basket of existing currencies into 4C. This will raise the 4C exchange rate and force some inflation in the currency basket. This financing mechanism may be called '*price pegging 4C to a climate mitigation schedule'*. To avoid political disharmony during policy implementation, the forced inflation should have the least impact on firms and citizens by spreading the inflation over the global economy. 4C is called a currency 'system' because it involves a dynamic pricing mechanism (G4CM Protocol) that is coupled to Integrated Assessment Models (IAM) for the climate and economic systems.

[3] '4C' is an abbreviation of the currency's technical name; not to be confused with 4°C.

Table 1. Proposed '4C' world currency for climate change mitigation (Chen & Cloud, 2014).

Mitigation Policy	*Global Complementary Currencies for Climate Change Mitigation* (G4CM) is the name of the mitigation policy. The G4CM Policy will create a world currency system to provide *Globalised Payments for Ecosystem Services* (GPES) (UNEP, 2007). Payments will be covered by inflation in fiat currencies under the *Beneficiary Pays Principle* (BPP). A G4CM Protocol is needed to manage the transfer of purchasing power from fiat into the new world currency based on expert advice and the results of Integrated Assessment Models (IAM).
Currency Name	*Complementary Currencies for Climate Change* (4C)
Unit of Account	100 kg of CO2-e verifiably mitigated (100 kg was chosen for convenience).
Medium of Exchange	Digital crypto-currencies and digital networks based on the internet, mobile phones, and banking systems.
Store of Value	4C will have a scheduled floor price, and this will involve 'pegging' 4C to hard currencies in a semi-fixed floating exchange rate system. This will be managed with an international monetary protocol called the G4CM Protocol. Value will also be created within currency markets as a result of market sentiment and as an expression of individual property rights regarding common pool resources (i.e. a social preference for stabilising the climate and protecting ecosystems).
Method of Issuance	Assessors will issue 4C to enterprises and collectives that have successfully mitigated. The 4C issuance may have conditions but it will generally be provided as a reward or subsidy without debt.
Social Agreement	Global subsidies will be offered for avoided GHG emissions, and global rewards will be offered for sequestered GHGs. Payments are justified under the BPP and costs will be spread across the global economy as inflation. Useful mitigation data that are collected will become public domain and shared globally.

2.3 Comparing 4C with Carbon Taxes

4C and carbon taxes are different in terms of their physical, informational, economic, and social relationships and so a comparison between the two market instruments is essential to our understanding of their potential roles in society. The initial assumption of 4C theory is that carbon taxes are naturally the jurisdiction of national governments, whereas 4C can be implemented as a world currency under international jurisdiction. A theoretical comparison is made between carbon taxes and 4C rewards/subsidies when applied 'at the chimneystack' (see Table 2). The principle information exchanges of the carbon tax and 4C are defined axiomatically, as follows:

Axiom 1: *The principle information exchange of (i) the carbon tax is for governments to collect macro-scale information on pollution from polluters; and (ii) the 4C is to deliver micro-scale information on mitigation to the world economy.*

As shown in Table 2, the entire ensemble of physical, informational, economic, and social relationships of the simple carbon tax and 4C are complementary and opposite (i.e. each relationship is axiomatic). For this reason, we conclude in principle that the carbon tax and 4C are 'complementary-opposites'. The following axiom describes their principle social relationships:

Axiom 2: *The principle social relationship of (i) the carbon tax is that governments impose carbon taxes on actors against their existing polluting activity; and (ii) 4C is that the world economy globally offers 4C to actors in return for their voluntary mitigation.*

The simple carbon tax and 4C both require a rising price schedule to encourage least cost mitigation. This leads to an additional axiom for price movements:

Axiom 3: *If least cost mitigation is sought, then the principle price movement of (i) carbon taxes is to rise to meet schedules under their respective national legislations; and (ii) 4C exchange rate is to rise under the combined demand of a global monetary protocol and globalised market sentiment.*

Table 2. The principle relationships of carbon taxes and 4C applied at the 'chimneystack'.

No.	Relationship	Simple Carbon Tax	4C
1	Physical Process	Direct Emissions	Mitigation of Direct Emissions
2	Physical Actor	Polluter	Mitigator
3	Economic Instrument	Tax	Currency
4	Economic Incentive	Penalty	Reward or Subsidy
5	Social Agreement Type	Instructional (Compulsory)	Invitational (Voluntary)
6	Social Authority over Actor	Yes	No
7	Information Instrument (Holder)	Tax (Government)	Currency (Currency Holder)
8	Information Type	Polluting Mass	Mitigated Mass
9	Information Scale	Macro	Micro
10	Social Initiator of Exchange	Government	Mitigator
11	Social Initiator's Action	Tax Law	Physical Mitigation
12	Social Initiator's Scale of Influence	Macro	Micro
13	Physical Response of Actor	Reduce Pollution	Increase Mitigation
14	Financial Impact on Actor	Rising Taxes	Rising Income
15	Economic Price Signal in Market	Rising Prices for Pollution	Falling Prices for Mitigation
16	Financial Recipient of Credits	Government	Mitigators
17	Financial Recipient of Debits	Market Actors	Economy-Wide
18	Economic Effect	Rising Prices (Biased) & Government Revenue	Falling Prices (Biased) & Fiat Inflation (Unbiased)

2.4 Socio-Economic Principles

Based on the market-and-monetary policy framework of 4C, and the market-and-tax policy framework of the simple carbon tax (refer Tables 1 and 2, and Axioms 1-3), the following four economic principles are deduced for the elemental market instruments and their respective policies:

Principle 1: *The carbon tax and 4C currency with opposing units of account are complementary market instruments and form a complementary pair.*

Principle 2: *The market-and-tax policy has (i) lower administrative overhead because payment-information is for pollution and administration is centralised by the authority; and (ii) price diffusion because prices follow goods and services as they flow through the market.*

Principle 3: *The market-and-monetary policy has (i) higher administrative overhead because payment-information is for mitigation and administration is decentralised in the market; and (ii) price preservation because prices follow currency as it flows through the economy.*

Principle 4: *The market-and-tax and market-and-monetary policies may be combined to create a 'policy-pair' with aggregated price signals and a single policy objective.*

Principles 2 and 3 tell us that the administrative overheads of the carbon tax may be lower than for 4C, but the higher administrative overhead of 4C is a trade-off for price preservation, a new currency, and the opportunity to develop an administrative system for public social networking, knowledge sharing, and 4C trading. A global 4C system will enable new long-term financing, price signal aggregation, socio-dynamic feedbacks, and improved market efficiencies.

The standard approach in economics does not articulate the above principles of complementary pairs and this is because the standard approach does not envisage unorthodox currencies, like 4C, with unusual accounting. Without 4C, or a similar currency, the opposing unit of account cannot globally exist in the standard economic model. Economic orthodoxy views carbon taxation and mitigation subsidies/rewards as policy alternatives based on fiat, and there is little cultural incentive to break with the fiat tradition because the fiat paradigm has a political hold. Based on Principles 1-4, it is concluded that adherence to fiat systems is a cultural bias that limits the economic theory and narrative of mitigation policy and it may even be preventing rapid progress on global climate mitigation.

Carbon credits/offsets that are traded within carbon markets, like the EU Emissions Trading Schemes (ETS), can have the same unit of account as 4C, but the difference is that carbon credits are not official currency. The lifespan of carbon credits is limited because the credits are used to balance total emissions with total pollution allowances that are enforced in the ETS. 4C cannot be substituted for carbon credits in the ETS, and the trade of carbon credits is not of general concern to the public and firms who are not part of an ETS. A major difference between 4C and carbon credits is that 4C will be an official world currency that can be recycled in the economy and traded in foreign exchange markets. The 4C administrative system would also be a public-domain network for social-knowledge sharing.

Principles 1-4 bring to the negotiating table a new approach of the policy-pair for aggregating price signals and creating dynamic socio-economic interactions and synergy.

Synergy effects may occur when there are overlapping of social-knowledge networks, price signals, socio-economic feedbacks, and information processing. Synergy effects could fundamentally alter civilisation as a system. This idea is formalised with the following premise:

Premise 1: *Complementary market policy-pairs with opposing units of account, such as a carbon tax and 4C currency, will combine synergistically to deliver a result that is superior to that of simple price signal aggregation.*

Premise 1 may be called the *Yin-Yang Effect* after the ancient Chinese philosophy of Yin & Yang. The essential understanding is that a balance of complementary-opposite elements in a physical, intellectual, social, or spiritual system can establish a new dynamic that transcends the apparent nature of the original system.

2.5 Global 4C Institutional Framework

New institutions, administrative systems, socio-economic relationships, and infrastructure are needed to implement 4C. These include a global digital currency network, a global currency market, and a global mitigation market as illustrated in Figure 1 and described below:

(i) **Global 4C Network:** a global 4C digital currency system, a global public 4C digital social-knowledge network, and programmable digital contracts.

(ii) **Global 4C Currency Market:** an international G4CM agreement, a G4CM monetary protocol, and an Integrated Assessment Model (IAM) that together can prescriptively influence 4C prices in world currency markets.

(iii) **Global 4C Mitigation Market:** a global 4C subsidy scheme, a global 4C reward scheme, and a decentralised administrative system that can collect mitigation data, assess mitigation amounts, verify mitigation amounts, and issue 4C payments.

G4CM can include the option for more than one 4C currency in the 4C system to accommodate diversity in policies, protocols, and rules that relate to currency convertibility and trade. It will be necessary that all available 4C currencies be issued in a single global mitigation market (see Fig. 1; Section 2.8), and will be traded within a single global currency market (see Fig.1; Section 2.7), and this is to ensure that 4C exchange rates equilibrate under the ‘Law of One Price’. Each 4C could be hosted by one national government and then economically supported by a club of nations. The 4C host nations may be the leading economies, such as the United States and China, who may negotiate monetary policy with other nations in their respective club. Each club will need to contribute sufficient economic support to achieve global equity.

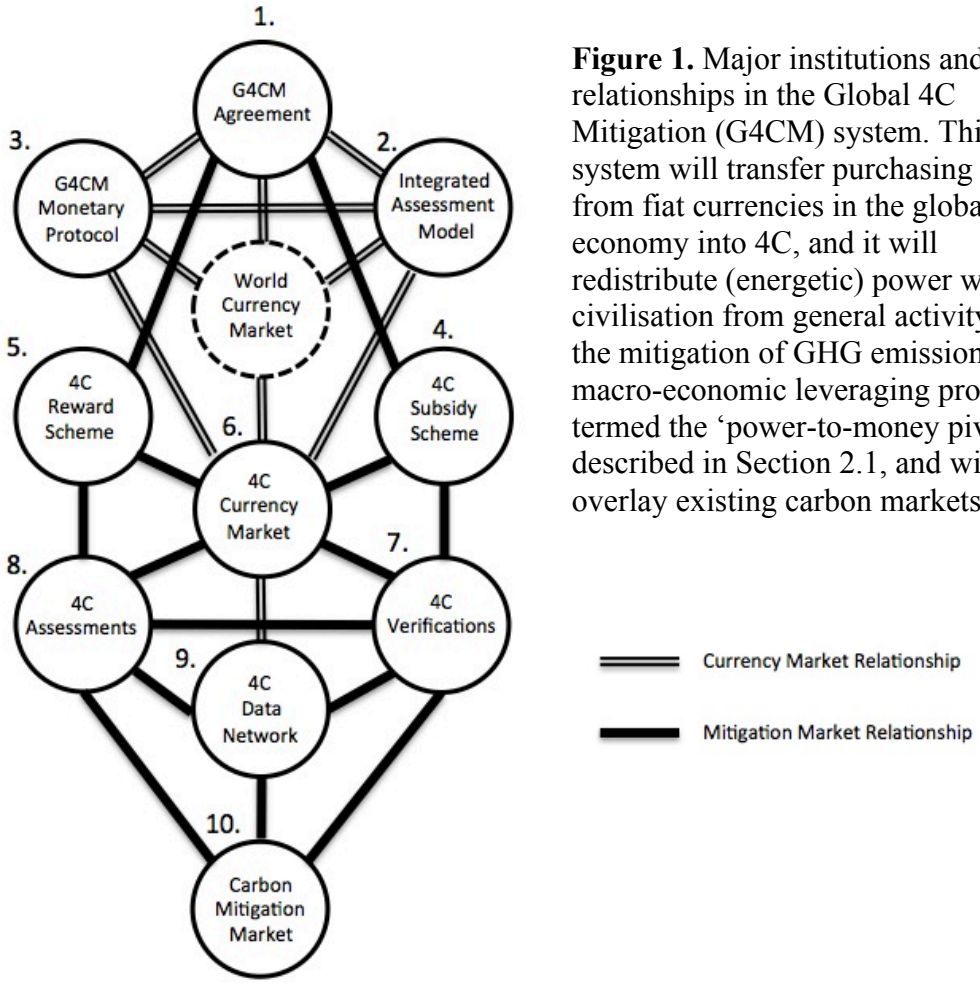


Figure 1. Major institutions and their relationships in the Global 4C Mitigation (G4CM) system. This system will transfer purchasing power from fiat currencies in the global economy into 4C, and it will redistribute (energetic) power within civilisation from general activity into the mitigation of GHG emissions. This macro-economic leveraging process is termed the 'power-to-money pivot', as described in Section 2.1, and will overlay existing carbon markets.

2.6 Global 4C Network

A feature of the G4CM Policy is the utility provided by a digital Global 4C Network (refer 9 in Fig. 1) for general administration of mitigation assessments, 4C commerce, project collaboration, instantaneous market knowledge, macro-economic reporting, and associated services (Chen & Cloud, 2014, Chen, 2014a, Chen 2014b, Chen et al, 2014). The Global 4C Network will be a 'public good' and a scalable worldwide social-knowledge network for all types of mitigation and 4C commerce. In this respect, the proposal brings to the table a new social potential based on information sharing. The G4CM policy will include a condition that useful mitigation data (collected from 4C awardees) shall become public domain.

The details of the Global 4C Network are beyond the scope of this paper, however the concept integrates tightly into the anticipated 'Third Industrial Revolution' (Rifkin, 2011) and the 'Internet of Things'. Turing-complete programmable currencies and digital contracts offer new potential efficiencies for e-commerce (Ethereum, 2015). The Global 4C Network should include mobile phones (esp. for rural communities) and should access financial and banking systems. The network should also link to geo-referenced satellite data and other databases relevant to mitigation assessments.

A first major insight into Bitcoin (Nakamoto, 2009) is of a technological nature. The internationalisation of Bitcoin illustrates the potential of internet-based digital currencies to provide a platform for developing an official supranational currency or world currency. It should be emphasised that Global 4C will not attempt to replicate the financial model and 'experience' of Bitcoin. The relevance of Bitcoin to Global 4C is the digital technology and Nakamoto's (2009) enabling theoretical innovation that underpins this technology. The enabling theory is a procedure for peer-to-peer (P2P) transactions without a trusted third party to prevent double spending, and a method for managing network (CPU) resources with a proof-of-work that records a sequence of events. This P2P procedure can be adapted or replicated to create a functional 4C currency system for the Global 4C Network (see 6. in Fig.1).

A second major insight into Bitcoin is of a political nature. Bitcoin was released without governmental agreements, and similarly 4C could also be released prior to international agreements over a G4CM policy. The political pathway of Bitcoin reflects upon the fact that the creation of fiat has two parts. The first part is to create the medium of exchange (e.g. banknotes, coins, digits), and the second is to establish a store of value with 'economic backing' (e.g. legal tender status, tax laws). The first part is administrative, but second requires a centralised authority such as a government. Hence Bitcoin was easily diffused throughout the world economy because it is only *administrative* and did not require authority. Consequently, the economic value of Bitcoin is a reflection of social preference and market sentiment. In some countries (e.g. Russia, China) there are restrictions on Bitcoin for domestic reasons. The insight is that 4C can be deployed as an administrative system prior to negotiations over a G4CM policy.

A long-term advantage of 4C built around a P2P network is that it may continue to operate if large parts of the network are adversely affected by natural disasters, civil conflict, or wars. In a future world troubled by dangerous climate change, a resilient network with redundancies may be helpful in continuing international trade and maintaining financial stability. Even today, before dangerous climate change takes hold, financial stability is not guaranteed (Korowicz, 2012).

2.7 Global 4C Currency Market

A key operational objective of the G4CM policy is to ensure that the 4C exchange rate exceeds a scheduled floor price. As illustrated in Figure 2, the 4C floor price will rise from a base of zero, and this is consistent with achieving 'least cost mitigation' (refer Axiom 3). Prior to the protocol's ratification, demand for 4C will be generated by social preference (see B in Fig. 2). After the protocol's ratification, a number of institutions will coordinate the 4C fixed trading to ensure that actual 4C prices stay above the assigned floor price (see C, D, and E in Fig. 2). The 4C floor price schedule will be revised at regular intervals by a panel of scientists and economists, and media statements will update the public and markets. Financial markets, mitigation markets, and the public will consider the 4C floor price schedule and will trade accordingly to maximise utility.

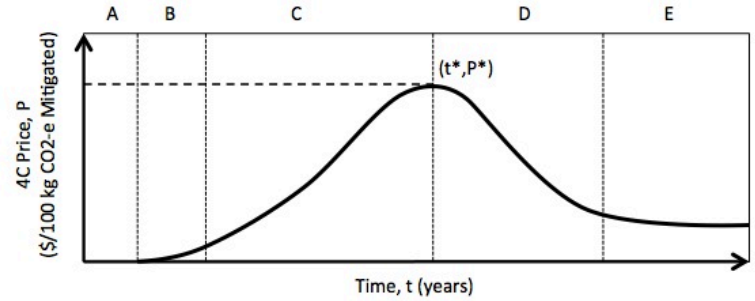


Figure 2. A hypothetical 4C floor price schedule with five major policy phases: (A) pre-policy; (B) pre-protocol; and protocol for (C) rising mitigation challenge, (D) falling mitigation challenge, and (E) quasi-steady mitigation.

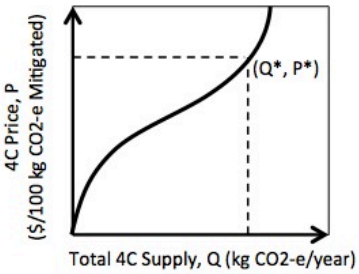


Figure 3. A hypothetical price-quantity relationship for total mitigation that receives 4C subsidies and rewards.

How exactly the 4C floor price will be managed by protocol is beyond the scope of this paper, however it is assumed that central banks and government institutions can design monetary policy for transferring purchasing power from national currencies into a 4C world currency. One such approach is called 'Green Quantitative Easing' (QE) (Ferron & Morel, 2014). This idea is similar to the concept of debt deleveraging (e.g. Dalio, 2014; Roxburgh et al., 2011) whereby climate mitigation would be treated as a 'debt'. An example of major debt deleveraging is the QE and economic stimulus coordinated by the U.S. Government and U.S. Federal Reserve during and after the 2007-9 global financial crisis (UNEP, 2009b).

Many variables will affect 4C supply, demand, and prices: including 4C fixed trading, investment demand, market speculation, total mitigation rates, trade, capital flows, climate system responses, carbon tax policies, technological innovations, and climate science. It is anticipated that a monetary protocol could be developed as a semi-autonomous program that adaptively executes 4C 'fixed trading' in markets to achieve the desired 4C price-quantity equilibrium over time (see Fig. 3). A panel of scientists and economists will oversee the protocol by focusing their attention on the resulting 4C price trends and the 4C price-quantity relationship.

The price-quantity relationship (Fig. 3) has social significance, because higher mitigation targets will require higher 4C prices. The 4C floor price is therefore a barometer for climate risk and can be used to communicate to the public the financial implications and risks of climate change. A more challenging mitigation scenario will create a steeper 4C price schedule (refer C in Fig. 3) and more bullish market sentiment will be the result. This socio-economic feedback will act as a 'negative feedback' on climate change. This negative feedback is a central feature of the policy, because it will assist the protocol's price objectives (i.e. 4C fixed trading) and it may synergy with social preferences for stronger mitgation.

The falling 4C price in phase D (Fig. 2) may give the impression that the currency market might collapse if prices are falling. There are options to prevent a price collapse during phase D, such as changes to reward and subsidy rules. Moreover, a society that has successfully achieved 'deep decarbonisation' will inevitably assign cultural value to 4C and will likely need it for many more decades/centuries to maintain safe GHG concentrations in the atmosphere. Phase E in Figure 2 represents a hypothetical long-term balance between total GHG emissions and total achieved drawdown of atmospheric carbon.

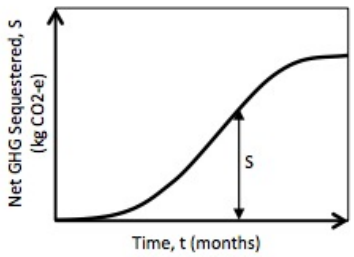
If the climate system approaches a tipping point (Caia et al., 2015), the 4C price will rise correspondingly. If the climate system actually enters a tipping point that exceeds humanity's capacity to mitigate (Schneider, 2013), it is speculated that the 4C floor price schedule will rise exponentially.

2.8 Global 4C Mitigation Market

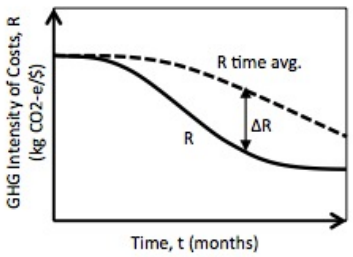
A key operational objective of the G4CM policy is to issue 4C subsidy and reward payments to service providers (i.e. mitigators) who have reduced GHG emissions or sequestered GHGs (Chen & Cloud, 2014, Chen 2014b, Chen et al, 2014). The G4CM policy will offer subsidies/rewards with some conditions to ensure mitigation effectiveness however the subsidies/rewards will be offered with attractive issuance terms that could be described as 'debt-free'.

The G4CM assessment rules will be designed to positively influence actors at the micro-economic level, and optimally influence markets at the macro-economic level. Assessment rules are explained below in terms of these essential concepts: direct/indirect emissions, industrial decarbonisation, cleaner power, carbon sequestration, safe storage duration, corruption, verification, commissions, mitigation defaults, conditional payments, and demurrage. Geo-engineering is not included in this G4CM policy because the 4C unit of account only addresses atmospheric GHGs.

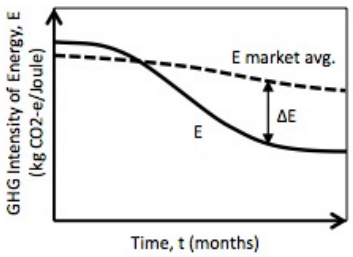
Figure 4. Metrics specifically recommended for calculating mitigation progress for (a) carbon sequestration, (b) industry decarbonisation, and (c) cleaner power supply.



(a) Sequestration: net GHG sequestered over time provides an absolute measure of stored GHGs.



(b) Industry: GHG intensity of operational costs is compared with the running time-average to provide a relative measure of avoided GHG emissions.



(c) Power Supply: GHG intensity of energy supplied is compared with the market average to provide a relative measure of avoided GHG emissions.

Carbon Sequestration: To bring physical rationality to the policy for sequestration, rewards for voluntary GHG sequestration will be determined from the net amount of CO_2-e mitigated during an assessment period (Fig. 4a). Safe storage duration needs to be defined as, say 100 years, and this duration will define certain terms of a contractual agreement for receiving 4C. Early release or leakage will trigger a 4C debit, and past 4C rewards may be reclaimed from the service provider to cover debts. If the service provider ultimately fails to repay a debt then the administrator will register the GHG debt as a 'default' and a corresponding amount of 4C

will be removed from circulation. Clearing of 4C defaults will occur as a demurrage charge applied uniformly to all holders of 4C. Note that demurrage can be administered with digital contracts built into the digital currency system.

Industry Decarbonisation: To bring physical rationality to the policy for industry, subsidies will be based on voluntary reductions in net direct GHG emissions over time and the assessment of whole physical systems (installations). Imbedded emissions in materials, outside services, and electricity are not included, and there is no need to assess energy efficiency. For all installations and businesses of any kind, small or large, a general rule can be applied based on reducing the net direct GHG emissions intensity of economic activity (Fig. 4b). The recommended metric is the ratio of net direct GHG emissions to operational expenses, R. If R falls below its running time-average by amount ΔR, then the installation is successfully mitigating. A 'fair' mass of GHG mitigated can be calculated from the ratio $\Delta R/R$ and the total direct emissions. This fair mass provides the basis for subsidy payments. The rule will encourage installations to continually decarbonise without penalizing growth. If R rises above the time average, then the installation will receive a 4C debit. Debts carry over into future assessment periods. If the installation defaults on its 4C debt, then the debt will be cleared as demurrage charges for all holders of 4C.

Cleaner Power Supply: To bring physical rationality to the policy for power supply, subsidies will be based on voluntary net direct GHG emissions and market statistics, and there is no need to assess energy efficiency. A comparison will be made between the GHG intensity of energy supplied by the installation (E), and the average GHG intensity of energy supplied by the relevant market (Fig. 4c). If a power installation can provide energy with lower emissions intensity than the market average, then they will be issued 4C subsidies. This approach favours continuous and competitive decarbonisation of power markets. The rules also contain variables to ensure that 4C subsides taper to zero when market share of a supplier reaches 100% (so that power suppliers do not become financially dependent on 4C). If the power supplier's energy becomes more polluting than the market average, the supplier will receive a 4C debit. Debts carry over into future assessment periods. If a power supplier defaults on their 4C debt, then the debt will be cleared as demurrage charges for all holders of 4C.

Administration: An administrative objective is to ensure that assessors, service providers (i.e. mitigators), and power producers do not collude to game the system. It seems unlikely that power suppliers would artificially raise emissions to financially benefit other suppliers, because of the cost of the fossil energy and carbon taxes, however there is still the possibility of collusion if producers of cleaner power were to share their 4C subsidies with producers of dirtier power. Power market collusion could be avoided with financial monitoring of 4C transfers within the digital network and public oversight.

Assessors will be paid with fixed commissions calculated as a percentage of 4C subsidies and rewards, and this is to encourage unbiased assessments. The commissions can be set in advance, by requiring mitigators to do a self-assessment and thus provide the value of the fixed commissions. The administrative system will independently select an assessor to undertake the final assessment for the mitigator from which subsidies/rewards will be calculated. If the results of the two assessments are significantly different, then the mitigator may be penalised with an administrative surcharge.

Verification of mitigation and related data will be the responsibility of assessors, inspectors, and a public trust system. All useful mitigation data that are collected will be

shared publicly to allow for public oversight and market efficiency. To further engender public trust in the system, each unit of 4C currency will be digitally linked to its originating assessment data. Participants (including administrators, mitigators, investors, traders, and public) will have private/public identities on the digital network, and will be invited to vote on services to express 'trust' in those services. In social networking 'trust' can be a currency in itself, and trust ratings may be used to incentivise good behaviour.

2.9 Dynamic Socio-Economic Feedbacks

The potential for socio-economic feedbacks is an important feature of this proposal. 4C could create the following dynamic socio-economic feedbacks that would incentivise markets to mitigate climate change:

(i) 4C price-signal aggregation with carbon taxes and influence on carbon trading markets (refer Section 2.9);
(ii) Profit motive synergy with environmental ethics, and resulting cultural changes and transformations in mainstream society, institutions and the media.
(iii) Positive market sentiment could provide very significant economic demand for 4C if a multi-decade bull market is required by the 4C floor price schedule, and this demand could be evaluated using Dow Theory.
(iv) Private trading and bargaining of currencies (i.e. 4C and fiat) as an expression of private ownership of common pool resources and to achieve a more efficient economic outcome for climate mitigation (i.e. Coase's Theorem).
(v) Political lobbying by sectors of the economy and the public who have a vested interest in rising 4C prices.
(vi) Instantaneous market knowledge through a global digital social-knowledge network for 4C trading and mitigation (refer Section 2.6).
(vii) Financial support for innovations in mitigation and potential technological breakthroughs.

2.10 Compatibility of 4C with Carbon Taxes

The carbon tax has a unit of account defined as 1000 kg CO_2-e pollution, and it is colloquially known as the "price on carbon". The 4C will have a unit of account of 100 kg of CO_2-e verifiably mitigated, and it may be colloquially known as the "reward for carbon". The accounting systems of the carbon tax and 4C are complementary and opposite. 4C will be deployed globally and in combination with existing national carbon taxes, carbon caps, and carbon markets as a policy-pair (refer Principles 1-4) and to create price signal aggregation. Synergy between the carbon taxes (Polluter Pays Principle) and 4C (Beneficiary Pays Principle) could have a culturally transformative influence (refer Premise 1).

A public offer of 4C subsidies and rewards will be for communities and enterprises everywhere, and so 4C price signals will overlay existing carbon markets, such as the EU Emissions Trading Scheme (ETS). 4C subsidies and rewards will encourage decarbonisation of installations in all markets. Scheme compatibility will be established with a policy directive that prevents enterprises from selling the same carbon credits to more than one scheme. For example, a forestry project that sells carbon credits to the EU ETS cannot earn 4C rewards for that same carbon. When 4C rewards for sequestered carbon rise to surpass the market prices for carbon offsets, the value of those carbon offsets will rise to meet the 4C reward.

The interplay between 4C exchange rates and the carbon tax (per tonne of CO_2) will have delayed social and political feedbacks. A high and rising 4C exchange rate will encourage politicians to raise the carbon tax in certain market sectors, because they will expect that firms that can decarbonise will be earning additional income from 4C subsidies.

3. Macro-Economic Sustainability Metrics

Emerging from the 4C approach are new macro-economic metrics and methodologies for sustainability. When the usual macro-economic metrics, such as total currency supply, Gross World Product (GWP), and Gross Domestic Product (GDP), are denominated in 4C, then they attain new and important physical, social, economic, and environmental meaning. When 4C circulates in the economy, we can express GWP in terms of its fiat and 4C components, as follows:

$$GWP = GWP_{fiat}\{\$\} + GWP_{4C}\{\$\} \qquad \textbf{Equation 1.}$$

Where,

GWP = Gross World Product valued in $
GWP_{fiat} = Component of the GWP denominated in fiat (i.e. non-4C)
GWP_{4C} = Component of the GWP denominated in 4C
$ = denoting the reference currency for valuation
4C = subscript denoting Complementary Currencies for Climate Change

A rising 4C exchange rate will lift 4C supply, and GWP_{4C} will also grow as a percentage of GWP. If the global economy has a growth bias, as indicated by its long-term productivity trend, then the GWP may continue to rise even when mitigation policies are reducing the GHG intensity of economic activity. If the G4CM policy objective is to reduce absolute GHG emissions but GHG emissions actually rise, then there would be an error in the application of the G4CM protocol. The protocol (possibly autonomous) should always adjust the 4C floor price schedule to reflect the global 4C price-quantity relationship that is observed. Restating this point, 4C prices and GWP_{4C} will increase under the protocol until the targeted mitigation result is achieved. The G4CM policy objective does not include GWP or GWP_{fiat} targets, as these are treated as responses of the economic system.

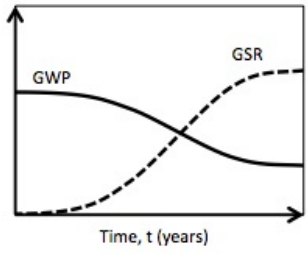
It may be a social or political preference for GWP to grow, for example to improve employment and increase profits, however as mentioned above, the G4CM policy does not include growth or de-growth as objectives. The G4CM policy is indifferent to social and political preferences for growth and so the decarbonisation objective (e.g. "Why a 4°C warmer world must be avoided" – World Bank, 2012) should be politically negotiated *a priori* to avoid 'misunderstandings'. The continuous economic commitment to decarbonisation may be expressed with the 4C floor price, inflation experienced by fiat currencies, and also with the following ratio called the *Gross Service Ratio* (GSR):

$$GSR_{4C} = GWP_{4C}/\ GWP \qquad \textbf{Equation 2.}$$

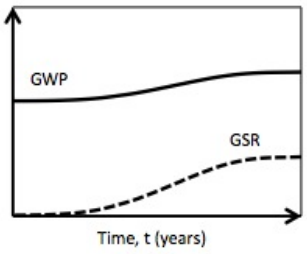
The GSR_{4C} is the ratio of GWP denominated in 4C relative to total GWP (see Fig. 5). GSR_{4C} has a maximum value of unity, and this will occur if the mitigation challenge demands 100% of global economic potential. This is a condition whereby the purchasing power of all

national currencies is fully transferred into 4C resulting in hyper-inflation in those currencies. This mitigation scenario may be notionally called the '*maximum economic mitigation potential*' of the G4CM monetary protocol.

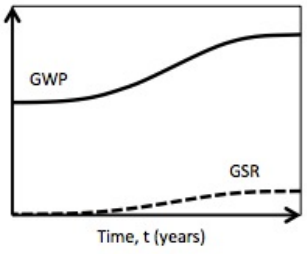
Figure 5. Gross World Product (GWP) and Gross Service Ratio (GSR_{4C}) as key metrics for discussing global decarbonisation, economic growth, and economic de-growth, especially when a positive growth bias is anticipated for the 21st century.



(a) High Difficulty: the global economy shrinks with decarbonisation as indicated by falling GWP. The GSR_{4C} is high as trade conducted in 4C is relatively large.



(b) Medium Difficulty: the global economy grows with decarbonisation as indicated by moderately rising GWP. The GSR_{4C} is moderately high and trade in 4C is moderate.



(c) Low Difficulty: the global economic grows with decarbonisation as indicated by rising GWP. The GSR_{4C} is relatively low as trade conducted in 4C relatively low.

Figure 5 shows three hypothetical mitigation scenarios as a function of time: (a) high mitigation difficulty, (b) medium mitigation difficulty, and (c) low mitigation difficulty. This figure provides a framework for discussing growth and de-growth as economic possibilities when the economy needs to be decarbonised. Factors that determine whether the economy experiences growth or de-growth during decarbonisation are beyond the scope of this paper, however some researchers argue that it will be necessary to have de-growth in the 21st century to stabilise the climate (e.g. Garrett, 2012a, 2012b).

MIT (2014) speculate that the UNFCCC post-2020 agreement at COP21 will not be stringent enough for stabilising emissions at 530-580 ppm CO_2-e by 2100. A post-2020 agreement may also have weaknesses because of emerging climate risks (refer Section 1) and also because some nations might default on pledges. A theoretical problem is that many IPCC (2014b) mitigation scenarios assume a global carbon tax price, early implementation of the tax, well-functioning markets, and availability of technologies – assumptions that are idealistic and perhaps untenable. A strategic and theoretical advantage of the G4CM policy is that 4C floor prices may be estimated for achieving the Copenhagen Accord (UNFCCC, 2009), or other objectives, when the post-2020 agreement is known. This flexibility derives from the G4CM protocol that will continuously manage 4C prices in foreign exchange currency markets.

4. World Service Currencies

The unit of account of the proposed 4C will be 100 kg CO_2 mitigated. If 4C is established as an official world currency, then it will require a new monetary classification. For this reason we propose the terms *Service Currency* (SC) and *World Service Currency* (WSC). SC's are currencies that have a unit of account defined by a fixed quantity of environmental or social service (possibly requiring proxy metrics). The WSC status applies when a SC is used worldwide and across national borders.

The WSC concept invites a new worldview of achieving long run sustainability with monetary protocols and GPES. The WSC worldview has some theoretical advantages, in that it is not based on ideological or political agendas (e.g. capitalism versus socialism) because the policy is constructed from elementary physical, informational, social, and economic principles. Citizens and firms everywhere will be able to trade with WSCs to express their ownership of common pool resources that are supported by the WSCs. The economic backing of WSCs is effectively the entire global economy, and this is assumed reasonable if WSCs are to be used to mitigate existential global damages and risks (RockstrÖm et al., 2009). For economic backing to be assured, a binding international agreement will be needed for each WSC. The political pathway to such agreements may be provided by field trials using digital currencies, followed by contingency planning, and then negotiations. Nations will be invited to participate in WSC systems for mutual protection. Participation will require ceding some fiscal sovereignty and monetary autonomy to each WSC protocol.

Another example of a WSC is the idea of a *World Peace Currency* (WPC). A WPC could be issued as a reward to people who advance peace, security, and nuclear disarmament (e.g. policy makers, negotiators, officials, military personnel, police, etc.). The WPC's unit of account should be based on *improvements* in peace and security. Metrics could include the *Global Peace Index* (GPI), for example. The GPI rates nations by on-going domestic and international conflict, violent deaths, international relations, criminality, political instability, terrorism, militarisation, and weaponisation.

5. Discussion

The G4CM proposal is presented within a framework of institutions, markets, and a 4C world currency all of which were derived from economic principles. Principle 1 defines the carbon tax and 4C as complementary economic instruments because they have opposing units of account. As mentioned in Table 1, the 4C unit of account is 100 kg of CO2-e verifiably *mitigated*, whereas carbon taxes typically have a unit of account of 1000 kg of CO2-e *pollution*. Principles 2-4 extend the idea of complementary-opposites to the market-based polices by calling them 'policy-pairs' when used simultaneously. Principles 1-4 and Premise 1 are explained metaphorically in Info. Box 1.

Principles 1 to 4 point to a new policy objective of aggregating price signals, and Premise 1 points to synergistic effects (i.e. socio-economic feedbacks). We may call this new objective the '*objective of the policy-pair*', and the synergy part of the objective is called the 'Yin-Yang Effect'. The intended objective of the G4CM policy is to combine with existing carbon taxes to 'bridge the gap' between mitigation commitments to be negotiated under the UNFCCC, and the mitigation commitments needed to meet the Copenhagen Accord (UNFCCC, 2009; i.e. <2°C of average global warming) or other goal that is achievable.

Information Box 1. Metaphor for systemic decarbonisation with carbon taxes and 4C rewards.

The complementary nature of carbon taxes and 4C may be described metaphorically by comparing the carbon tax approach to a circulatory system, and 4C approach to a nervous system with a brain.

Circulatory System: The carbon tax creates a price signal that attaches to goods and services, and so the price signal actually 'flows' through the economy with these goods and services. We can compare goods and services to blood cells, and the price signal is a change in blood pressure within the circulatory system. The carbon tax represents a reduction in blood pressure targeted at organs of the body where CO_2 is created, and this is to reduce the rate of CO_2 produced.

Nervous System: The 4C currency-reward network creates a price that is attached to information packets moving in the economy, similar to the flow of electric signals in a nervous system. The 4C price is the electric potential (voltage) and a mass of CO_2 reduced is coded into the electrical signal. The 4C network offers cells additional electric potential if they reduce CO_2. Each cell likes to have electric potential to trade for nutrients with other cells, and so many cells try to reduce CO_2 to receive the 4C electric potential.

Brain: The brain creates a map of previous signals in the nervous system (i.e. a neural network). As the map becomes more sophisticated, cells and organs are able to coordinate their resources better to improve their capacity to reduce CO_2. As the map evolves, the brain becomes more 'intelligent', and it controls electric potential more precisely and develops skills to influence the blood pressure and other bodily processes to optimise CO_2 reduction. This is an emergent property of the network-pair in the system (refer Premise 1).

Footnote: The beginnings of the 'neural network' could be mapped from the 4C financial relationships and mitigation data contained in the public domain 4C digital network. In the real world economy, the future location and form of this 'brain' may exist as a combination of distributed and concentrated centres of intelligence.

Political and economic issues are raised by this G4CM proposal for a 4C world currency. G4CM may produce a new generation of market policies for climate mitigation and as such the debate over 'market versus state intervention' to mitigate climate change (e.g. Nápoles, 2014) appears incomplete without G4CM. Whilst there may be a role for both market based and interventionist approaches, the G4CM proposal begs the question of whether the full potential of market based approaches has been assessed. We argue that it has not, because the G4CM policy has yet to be analysed and tested. The G4CM proposal may be an invitation to a new worldview in market economics because the proposal identifies and utilises a new globalised price instrument.

The G4CM Policy begins with designing and implementing the Global 4C Network and Global 4C Market to circulate 4C in the economy. This process can/should begin without a monetary protocol (refer B in Fig. 2). The aim of 4C in the early phase of deployment is to

draw trust into the central G4CM institution. 4C can/should be established within an existing or new global governance institution (Dryzek, 2014) that can earn the 'trust' of stakeholders and will invite actors to participate for benefits, including (i) 4C subsidies/rewards for mitigation, and (ii) business opportunities to develop the infrastructure and administration for a world currency. While participation grows organically, the 4C system will attract political interest and this will buoy-up the 4C price during Phase B (refer Fig. 2). Speculative price rises will create self-reinforcing socio-economic feedbacks that may open a political pathway to international G4CM agreements and protocols.

The issue of the Triffen Dilemma (refer Section 1.3) may be raised with the G4CM proposal, but the proposal is not aimed as resolving this dilemma. G4CM has only one primary objective: to mitigate GHG emissions for improving welfare and preserving ecosystems. The singular G4CM objective is supported by the Tinbergen Rule, which recommends one objective per policy. The cost of meeting the Copenhagen Accord (UNFCCC, 2009) has been estimated to be about 4-5% of consumption (IPCC, 2014), and this gives an indication as to the potential for 4C as a reserve currency. In any case, GWP denominated in 4C should only match that required to achieve the primary objective (refer Section 3 and Fig. 5). If 4C becomes a reserve currency, then this may be viewed as a co-benefit assuming that economic conditions are improved. Such co-benefits may echo the double-dividend hypothesis (Schöb, 2002) for environmental taxes that improve non-environmental welfare.

A socio-economic strategy of the G4CM policy is to allow qualified citizens and firms to undertake the assessment of mitigation by inviting them to join a decentralised global administrative network. Communities and enterprises in any location may then submit their mitigation data to this administrative network for 4C subsidies and rewards. The provision of the digital social network and public domain data will encourage innovation, collaboration, coordination, communication, and efficient capital investment. The G4CM policy also meets key criteria for an effective market-based policy (Nordhaus, 2013; Stavins, 1997), including scope to (i) internalise the costs of climate mitigation into the economy (with inflation); (ii) attract maximum participation with global price signals, rewards, and subsidies for mitigation markets; (iii) aggregate with price signals of carbon taxes and ability to raise the value of carbon offsets in carbon markets; (iv) provide specific rules for the assessment of specific industries; (v) advertise price schedules for forward planning; (vi) establish floor price estimates with increasing stringency and based on cost-benefit, risk assessment, and IAM analyses; and (vii) rapidly adjust floor prices in response to emerging climate change and other time-dependent variables.

Possibly the most important issue to be raised by this exposition is a comparison of the political pathways for the market-and-tax policy (i.e. carbon taxes) and the market-and-monetary policy (i.e. 4C). As mentioned in the introduction, centralised political power and authority are needed to implement carbon taxes, but the world is culturally and politically diverse, and trying to solve a global problem with a centralised authority may not be feasible (e.g. Stavins, 1997). The 4C, on the other hand, diffuses authority into society because actors are invited to mitigate GHGs to receive 4C subsidies/rewards. It is postulated that the policy-pair actually invite complementary-opposite political pathways. It is recommended that policy makers identify and exploit these political differences.

There is popular dissatisfaction with the GDP metric because it ignores social and environmental progress however our common definition of GDP cannot be altered.

Introduced with this proposal is the concept of segregating GDP and GWP according to their fiat and 4C components (refer Equation 1). This offers a partial resolution by keeping the metric definition and introducing a new unit of account (i.e. 4C) that quantifies a critical environmental variable. This new approach may help resolve our controversial use of GDP as a metric (e.g. Ven den Berg & Antal, 2014). There is another question that has yet to be articulated, and this relates to cost-benefit analysis with a common currency. If a heterogeneous currency system is used (e.g. fiat and 4C) is it reasonable to segregate the cost-benefit analysis by currency type? If so, how does this impact our interpretations of costs and benefits?

The idea of using a 4C world service currency to mitigate climate change and provide a pathway to long run sustainability opens the door to new relationships with money. Ever since money was used in ancient Mesopotamia it became the tool of choice for nation building and nation destroying. In the early 21st century we are faced with global scale environmental, financial, social, and political challenges (UNEP, 2009b). Lietaer et al., (2012) and others have already identified a need to innovate currencies for sustainability, but we need economists, bankers, scientists, and policy makers to act by creating a new global governance role for a specific new type of money. This is necessary when there is no clear roadmap to global sustainability within the paradigms of gold, silver, and fiat.

At the time of writing, seventeen leading scientists and economists, including Lord Nicolas Stern (Stern et al., 2015), released 'The Earth Statement' that recommends eight essential elements of climate action for negotiations leading up to the UNFCCC's COP21 meeting to be held in Paris, December 2015. We give G4CM a review in terms of these eight recommendations (see Table 3).

In conclusion, this exposition is founded on one simple idea: accounting. The national carbon tax is a penalty for polluting, and the international 4C currency is a reward for mitigating. When these pricing instruments are assigned opposing 'units of account' they form complementary-opposites and the 'atoms' for a new economic Universe.

6. Recommendations

The theory presented here defines the carbon tax and a 4C world currency as complementary market instruments that can be applied in a policy-pair. This is a work in progress, and a complete theoretical treatise is recommended, perhaps as a '*Unified Theory of Complementary Pricing*' (?). Future theory will frame the policy-pair objectives, the price-quantity equilibrium, the social-economic network/system, and cultural references. Individuals and institutions are cordially invited to contact the lead author and Jonathan Cloud (http://www.global4c.org) to collaborate on this project. Moreover, because of the critical nature of climate change, we request that this paper be urgently disseminated to peers for review and to potential new partners and sponsors for a feasibility study.

Table 3. 'The Earth Statement' and the G4CM proposal

Recommended Climate Actions (Stern et al., 2015)	G4CM Proposal (Chen & Cloud, 2014; Chen, Phu & Carbonneau, 2014; Chen, 2014a, Chen, 2014b; Chen, Cloud, Gray & van der Beek, 2014)
1. Governments must put into practice their commitment to limit global warming to below 2°C. We should aim to stay as far below it as possible, since even 2°C warming will cause significant damage and disruption.	1. G4CM invites a monetary protocol that will raise the floor price of a 4C world currency in exchange rate markets until market forces are sufficient to mitigate GHG emissions for <2°C warming. The 4C price signal will complement carbon taxes.
2. The remaining global carbon budget – the limit of what we can still emit in the future –- must be well below 1000 Gt CO_2 to have a reasonable chance to hold the 2°C line	2. 4C is world currency system that can operate for centuries into the future in concert with taxes and regulations to ensure that atmospheric GHGs are constrained.
3. We need to fundamentally transform the economy and adopt a global goal to phase out greenhouse gases completely by mid--century.	3. G4CM provides a fundamental change to the economy to phase out GHG emissions. Orthodox instruments (e.g. taxes, transfer payments, bond issues, charity, loans etc.) do not provide this global systemic coordination.
4. Equity is critical for a successful global agreement in Paris. Every country must formulate an emissions pathway consistent with deep 22ecarbonisation.	4. G4CM offers all citizens everywhere the opportunity to earn rewards for reforestation, improved land management, and all other types of mitigation. Equitable cost sharing is negotiated within an international monetary protocol.
5. We must unleash a wave of climate innovation for the global good, and enable universal access to the solutions we already have.	5. G4CM will provide long-term stimulus directly targeted at mitigation results and will avoid financial intermediaries. The 4C digital network is a social-knowledge network for 'a wave of climate innovation'.
6. We need a global strategy to reduce vulnerability, build resilience and deal with loss and damage of communities from climate impacts, including collective action and scaled--up support.	6. G4CM is a global strategy that can improve social cohesion and build resilience with activities that mitigate GHG emissions. 4C can be traded through mobile phones where/when infrastructure is vulnerable.
7. We must safeguard carbon sinks and vital ecosystems, which is as important for climate protection as the reduction of emissions.	7. G4CM offers rewards for bio-sequestration, and this will include rewards for avoided deforestation based on statistical rules (refer Chen, 2014b)
8. We must urgently realize new scales and sources of climate finance for developing countries to enable our rapid transition to zero--carbon, climate--resilient societies.	8. G4CM creates a monetary protocol that will create a long-term and reliable source of global finance through a process of fixed currency trading (and without taxes). The costs will be dispersed as inflation in the world economy with least impact on individuals and firms.

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