WHITEPAPER

A Climate-Innovation Perspective on the Fourth Industrial Revolution

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The fourth industrial revolution is rapidly emerging and offers extraordinary innovation potential. In particular the combination of the 'troika' of IoT (Internet of Things), DLT (Distributed Ledgers, 'Blockchain'), and AI (Artificial intelligent) is disruptive and carries wide reaching opportunities. This is relevant for all industries, and of course also concerns climate. Very significant is the impact on measuring/monitoring, reporting, and verification (MRV), with 'digital MRV' arriving. For regulators and innovators, the innovation tsunami induced by the fourth industrial revolution has profound implications. Key is to develop secure and open systems, offering interoperability as well as transparent data sharing policies and consensus mechanisms. If addressed correctly, fourth industrial revolution related innovation has the potential to significantly increase the transition speed of decarbonisation and thus majorly impact our potential to implement the Paris Agreement on climate change and reach net-zero tCO_2e emissions by 2050.

ABOUT THE AUTHOR

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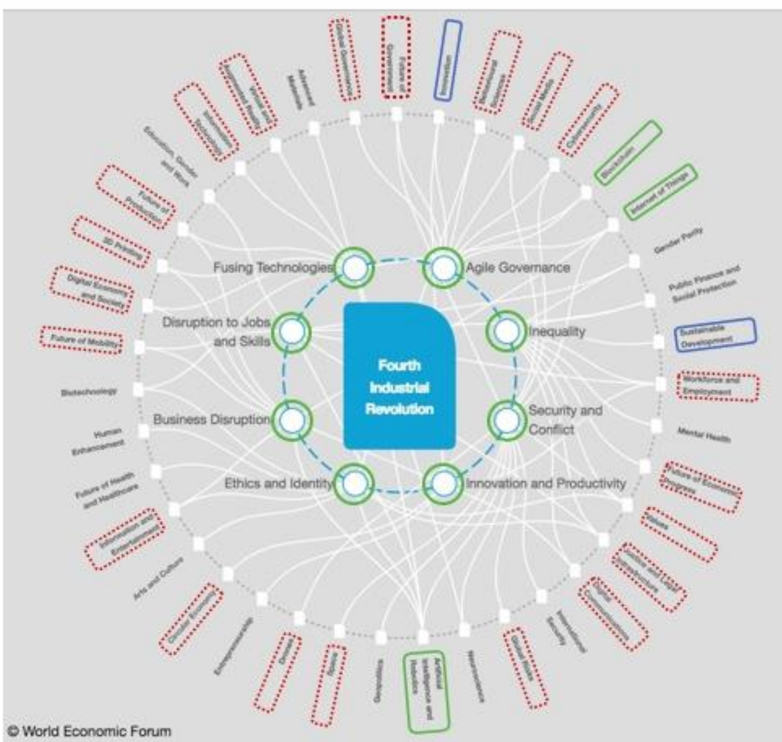
1. Welcome the Fourth Industrial Revolution

The 'fourth industrial revolution[1]' is upon us. It is all about networks and connectivity for new forms of collaboration, new industry ecosystems – similar to what we have witnessed in the advent of the previous industrial revolutions. From a technical viewpoint, it is driven by many different innovation areas. These include 'upgrades' of major communication infrastructure (such as 5G[2] mobile data exchange or next generation remote sensing), as well as of entirely new industry ecosystems (such as with digitally-enabled, peer-to-peer energy networks[3]). Most of all, the fourth industrial revolution is driven by better, network-enabled, data sensing and analysis, and by distributed systems allowing trusted exchange of digital value. The resulting innovation is powerful and may lead to exponential product and service improvements, and it may disrupt incumbent processes, alliances, and organisations.

Particularly disruptive, and powerful in combination, is the 'troika' of innovation areas (1) Internet of Things (IoT), (2) Distributed Ledgers (aka 'blockchain', including 'Smart Contracts'), and (3) Artificial Intelligence (AI)[4]. This may first sound as a combination of buzz words, but there are many reasons for their exponential innovation powers, in terms of technology/business and society/governance. Fundamentally,



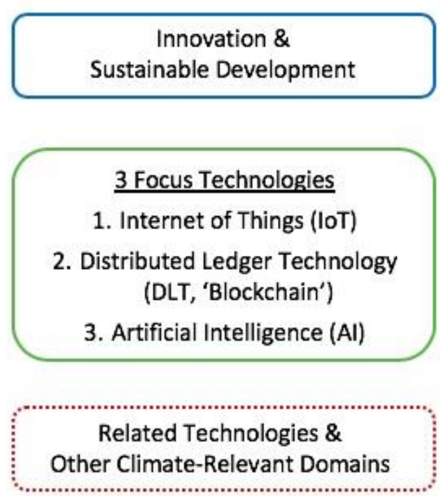


Image: Left section ©WEF, complemented by C21's analysis

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[1] Exemplary source: 'The Fourth Industrial Revolution: what it means, how to respond', World Economic Forum (WEF), 14/01/2016, https://bit.ly/1pBfye4

[2] https://en.wikipedia.org/wiki/5G

[3] 'Peer to Peet Energy Trading in a Microgrid, Chenghua Zhang & others (15/06/2018), https://bit.ly/2Su4OhN

[4] Exemplary source: 'The Blockchain-enabled intelligent IT economy', Medium (13/10/2018), https://bit.ly/2zawfUQ

the world is becoming digital, and is also moving to more distributed systems – empowered by the disruptive technology-troika.

In fact, the troika gets its power from being highly conducive to three macro-trends underlying the fourth industrial revolution – decentralisation, sharing, and automation. In many cases, distributed, i.e. decentralised systems where transactions occur between distributed peers**,** are superior to centralised ones. Proper data sharing and incentive structures can result in innovative business models with automated transactions as well as economic advantages from sharing, leveraging what is called 'excess capacity'[5] (for example people renting out their 'excess' room to Airbnb).

These advantages become apparent in a wide range of application fields, from network communication (with the most prominent example being the Internet), to finance (incl. crypto currencies). 'Distributed' often means safer and more transparent. It also allows all users/stakeholders to remain in control of their data and to enjoy privacy and ownership advantages (e.g. monetising their energy data). This, in turn, is supportive to more sharing and automation. Increasingly, 'peer to peer' will relate to 'humans to humans' as well as 'machines to machines'.

These are five exemplary 'disruptive' use cases:

1. Not a few large and expensive government-owned sensors, but thousands of small and inexpensive ones, in each city and across remote regions, run by private companies and citizens on their infrastructure or balconies, capturing and sharing data (e.g. for emission monitoring or detailed weather forecasting with a view to cloud-prediction for PV-based energy generation);
2. Prosumers are tapping their own PV and battery power first ('self-consumption'), and then trade energy peer-to-peer as part of energy communities. Thereby the entire network management and market making logic translates from top-down, with central power plants and electricity traveling long distances over high voltage networks, to bottom-up, with the 'prosumer' being at the centre and electricity being distributed with the shortest-possible distance so as to minimise infrastructure cost and maximise resilience;
3. EVs, shared by many, in distributed ownership, and paid for based on the specific, measured/exact distance travelled (as well as driving style) by each authorised user/owner;
4. Networks of 3D printers, producing customised parts locally, from valuable designs licensed digitally and linked to transparent, automated payment processes;
5. Tokenised[6] large reforestation projects or individual small-scale farms as 'democratised' impact investments, distributed among many small private investors committed to climate action.

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[5] The term was coined by Robin Chase, see for example: https://whr.tn/1R2Zjws
[6] 'Tokenization of assets' is linked to 'securitization', exemplary source: https://bit.ly/2Cyh8cR

2. The distributed/disruptive troika of IoT, DLT & AI

It is **IoT**[7] that 'captures' more and more data ('big data') and makes devices smart, so that they can be managed over networks ('machine to machine'). This, for example, allows autopilots to link-up to save energy by building columns on highways. Heat-pumps can balance electricity load with EVs, and drones perform automated tasks based on soil-sensor readings. IoT is said to explode over the coming decades into billions, if not trillions of devices and resulting oceans of data[8], with more and more business and consumer devices becoming 'smart'.

AI[9] encompasses a range of different fields. Fundamentally, it helps us to learn from analysing large amounts of data. All kinds of data can be put to work in order to learn from the past, automate ongoing processes, and predict the future based on recognised patterns. This makes AI an incredibly powerful tool. It finds application opportunities in almost any industry and offers many climate-relevant application possibilities[10] - from making better decisions regarding climate-related investments, to automated verification as part of impact monitoring schemes.

'In between' and at the core, of sorts, is Distributed Ledger Technology (**DLT**[11]), one form of which being the notorious Blockchain[12]. Even though it is still early days, and scalability as well as power consumption challenges of the current generation DLT need to be addressed[13], it must be regarded as a very significant innovation driver – according to the WEF, 'on par with the Internet'[14]. Yes, there is hype and speculation (particularly concerning 'ICOs'[15]). But what The Economist called 'the Trust Machine' just

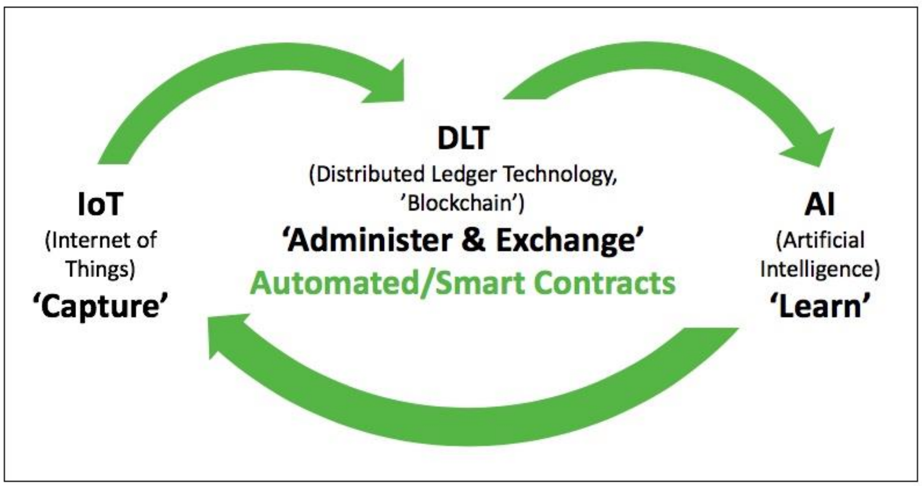

Image: IoT/DLT/AI Schematic, ©Cleantech21, 12/2017

[7] https://en.wikipedia.org/wiki/Internet_of_things
[8] Exemplary source: 'ARM predicts 1 trillion IoT devices by 2035 with new end-to-end platform' ITU (06/08/2018), https://news.itu.int/arm-pelion-iot-end-to-end-platform/
[9] https://en.wikipedia.org/wiki/Artificial_intelligence
[10] Exemplary source: 'Artificial Intelligence Industry, An Overview by Segment', TE (16/09/2018), https://bit.ly/2GqUzo7
[11] https://en.wikipedia.org/wiki/Distributed_ledger
[12] https://en.wikipedia.org/wiki/Blockchain
[13] Exemplary source: CleanCoins project, http://www.cleancoins.io
[14] Exemplary source: 'Realizing the Potential of Blockchain', WEF (28/06/2017), https://bit.ly/2uio7O1
[15] 'Initial Coin Offering (ICO)', or 'Token Generating Event' (TGE), https://en.wikipedia.org/wiki/Initial_coin_offering

prior to COP21 (09/2015)[16], is to be taken even more seriously when now approaching COP24 (12/2019). This is because of that trust element of DLT. In the words of one prominent promotor, it allows us to step-up from the 'Internet of information' (websites, copying one email to a 1'000 recipients), to the 'internet of value' (surf and email, as well as transfer unique digital assets/value in a trusted way)[17]. This enables things like digital currencies, which no user should be able to copy. At its core, DLT thus allows users ('peers'), who don't trust each other, to exchange value in the form of digital assets, directly between each other ('peer to peer'), without requiring a central authority to validate transactions (no 'middleman'). Validation is based on distributed 'consensus mechanisms'[18] (e.g. 'proof of work'[19] for the Bitcoin blockchain, 'proof of stake'[20] as is planned for Ethereum, or novel DAG-based[21] approaches such as Hedera or IOTA).

If DLT is combined with IoT and AI, **dynamic systems** can emerge[22]. Data by the smart weather stations of distributed users can be stored on and linked to a distributed ledger, and shared via a 'marketplace' for such data[23]. Humans and machines can buy and sell data, and also collectively put it to work in terms of AI[24]. The AI-lessons learnt can be shared, with the same marketplace logic – for example to coordinate energy-consuming devices as part of the energy grid. This leads to better, automated market decisions (such as when to battery-store or to sell energy). As part of these distributed systems, individual devices (on behalf of their owners) can send and receive micropayments directly. For this to work, peers, and their

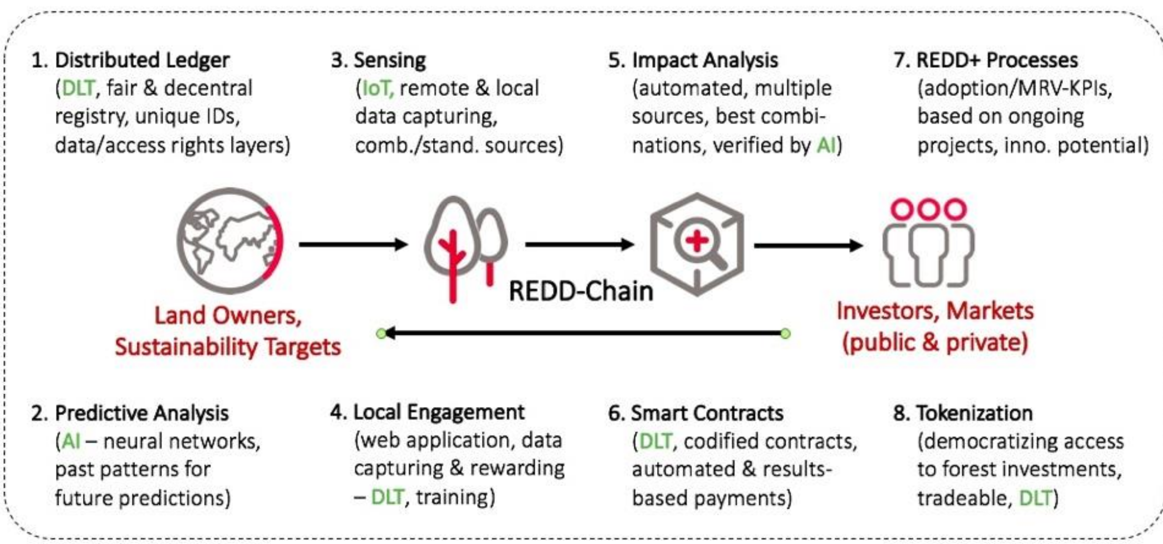

Image: REDD-Chain, incl. GainForest, Value Proposition Overview, 06/2018

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[16] 'The Trust Machine', The Economist (31/10/2015), https://econ.st/2qmNbUh
[17] A term coined by Don & Alex Tapscott, https://bit.ly/2nW03ix
[18] Exemplary source: Investopedia (accesses 31/10/2018), https://bit.ly/2QUT5HQ
[19] https://en.wikipedia.org/wiki/Proof-of-work_system
[20] https://en.wikipedia.org/wiki/Proof-of-stake
[21] https://en.wikipedia.org/wiki/Directed_acyclic_graph
[22] Exemplary source: 'The Convergence of Blockchain, IoT and AI, Intellipaat (03/09/2018), https://bit.ly/2Bfc7Dq
[23] Example: IOTA Marketplace, https://data.iota.org/#/
[24] Exemplary source: 'The Applications of Blockchain in Big Data', Hackernoon (10/05/2018), https://bit.ly/2AwVe6E

devices, need to be uniquely identified and trusted. Sharing terms are set and coordinated among peers with the help of service provider-platforms (who themselves may represent 'decentralised autonomous organisations'[25]). This is done (e.g. for an energy community) with 'smart contracts' essentially containing electronic terms that can self-execute (general ones peers sign-up to, or specific ones with 'project-peers').

3. Social dimension

In addition to these technical and process aspects, the connection between DLT and IoT/AI has a strong **social dimension**[26]. This is because, from a governance/policy perspective, it should be avoided that the innovation power of those technologies (and many related technologies) remains in the hands of a select few. This could lead to an unhealthy concentration of power and would further increase challenges with data privacy. In the wake of the fourth industrial revolution and given the data 'tsunami' that comes with it, finding solutions is urgent[27],. Best, power is distributed among many, and that is exactly what can be enabled by DLT[28]. As per the above energy example, the community can collectively learn by each member individually sharing data, with a benefit to all in the community[29].

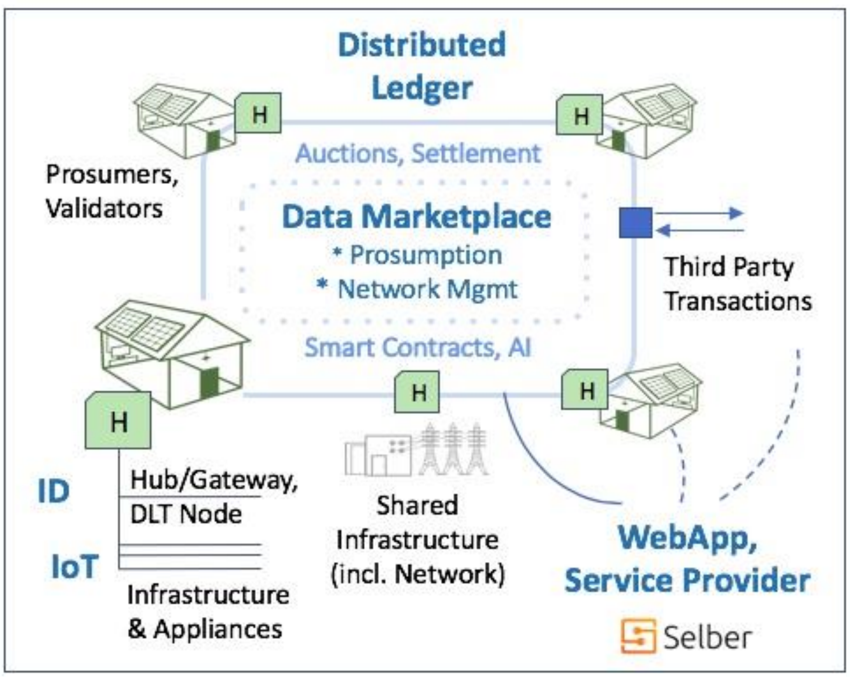

Image: Selber, Value Proposition Overview, 02/2018

[25] https://en.wikipedia.org/wiki/Decentralized_autonomous_organization
[26] Exemplary source: 'How the Blockchain Could Break Big Tech's Hold on AI', The New York Times (20/10/2018), https://nyti.ms/2S2jGDw
[27] Exemplary source: 'Ready for the digital tsunami?', The Conversation (29/08/2018), https://bit.ly/2Awy0Oc
[28] Exemplary source: Ocean Protocol (accessed 21/10/2018), https://oceanprotocol.com/
[29] Exemplary source (from this author) on distributed energy, Medium (09/03/2018), https://bit.ly/2AuXNpK

4. Real world challenges, lessons learnt for regulators & innovators

The potential of employing these technologies and leveraging their innovation power for climate action is obvious. It applies not just to selected, but to many different processes and methodologies of direct climate relevance[30]. For innovation to be tangible/applicable to **real-world challenges**, it is paramount that:

1. International and national regulatory frameworks are compatible with the new technology and the innovative processes and methodologies it may offer;
2. All stakeholders apply the technology with open data[31] practices, assuring interoperability across projects, stakeholders, and borders[32].

A DLT solution, for example, may have much superior attributes in terms of trust, security and transparency, but the prevailing regulations on data protection (e.g. requiring a certain type of data to be nationally hosted) may not yet allow its deployment[33]. Similarly, a standard may define a certain set of processes and methodologies that no longer make sense with fourth industrial revolution possibilities.

For **regulators** and Paris Agreement Rulebook[34] negotiators, this demonstrates the need to focus on standards in the form of performance/quality level of data – and stay away from regulating specific process steps and methodologies. In many industries, regulators will find that frameworks will need upgrades in order to cater to distributed systems. As is currently observed in energy, for example, the fundamental logic of regulation will soon turn from 'top-down' to 'bottom-up'[35]. Additionally, it seems important that investor protection and data privacy rules, as are currently being discussed in many countries, are further developed and help to provide much needed regulatory transparency and security, while not unduly inhibiting the adoption of innovative technology and fundraising practices by honest innovators. The trust-element of DLT is particularly interesting for regulators. It has the potential to lead to novel regulatory approaches with unprecedented levels of transparency and efficiency. A tax/dividend scheme for pricing GHG emissions, for example, could be operated in a highly transparent way, such that citizens can specifically monitor the use/distribution of tax income, what, in turn, may alter the political feasibility and adoption of introducing a tax[36]. Similarly, stakeholders can be incentivised to share more data, for example

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[30] The United Nations framework itself can be regarded as being, in essence, a consensus challenge of equal peers.
[31] https://en.wikipedia.org/wiki/Open_data
[32] The interoperability of different types of distributed ledgers is a topic finding much attention. It is generally recognized that both permissioned and permission-less ledgers are most useful if they are interoperable with other ledgers. Exemplary source: 'Accenture Tech Now Connects Corda, Fabric, DA, and Quorum Bockchains', CoinDesk (22/10/2018), https://bit.ly/2D3odBG
[33] Noteworthy is the current discussion on DLT and GDPR. Exemplary source: 'The GDPR and Blockchain', Inside Privacy (24/07/2018), https://bit.ly/2Pos6qA
[34] Exemplary source: 'Bangkok Climate Talks: Time to Deliver Real Progress on the Paris Agreement Rulebook', WRI (29/08/2018), https://bit.ly/2wzSNNt
[35] Exemplary source: 'How Joseph Lubin's Power Moves Will Further Stir the Blockchain Power Plot', Forbes (23/10/2018), https://bit.ly/2D9ulrN
[36] See related publication by Cleantech21 (11/2018)

in value chains, due to greater transparency, higher security and because they remain in control of the data they share, and because they may be able to monetize shared data in new ways.

Innovators in the private sector need to prepare for the disruption which the technologies of the fourth industrial revolution are likely to bring to their industry. They are presented with opportunities in which new technology can empower existing practices, and others, for which entirely new processes are most efficient. Often, evaluating the application options of exponential technologies may also lead to business model and process innovations that are not directly related to the technology, but are rather the result of a 'fresh' look at current practices. Successful use cases have teams that combine and are able to 'merge' technology- and process-knowhow/expertise[37].

Image: Agricultural drone equipped with LiDAR, photo courtesy of UF/IFAS

5. Digital MRV

For both regulators and innovators, disruptive innovation will have profound effect in the area of Measurement, Reporting and Verification (MRV), which is sometimes referred to as **'digital MRV'**. Its implications are fundamental, requiring the re-thinking of the 'what' and the 'how' in MRV processes. The specific applications of digital MRV is largely dependent upon the actual use case – very different for monitoring land-use change than for biological produce, biodiversity, or child labour.

A number of digital MRV/impact verification **platforms** are emerging, attempting to standardise and simplify MRV tasks. In particular, this seems to make sense with respect to different stakeholders cooperating, e.g. agreeing on data sharing terms, setting KPIs. Several pilot projects are beginning to gain

[37] Exemplary source: 'The Truth about Blockchain', Harvard Business Review (02/2017), https://bit.ly/2hqo3FU

experience in particular MRV fields (such as land use management or energy). Some of these may expand to 'vertical' solution specialists, able to offer standardised solutions for specific sets of MRV data (such as multi-source satellite imagery and image-processing algorithms[38]).

For a further **outlook** on 'digital MRV', these developments and trends seem relevant:

- It is increasingly feasible to monitor all kinds of activities at scale, in situ and remotely[39].
- The resulting systems allow for more, automated, and real-time reporting and verification of actual measurement results. Thereby, MRV will transit from estimates and extrapolations to actuals.
- With better tools to capture, administer/exchange and analyse data, MRV quality can be expected to increase substantially[40]. Even though new challenges arise (e.g. large-scale digital theft), more data at better quality, and more and automated analysis to verify and report that data, are expected to lead to substantial progress in MRV. For example, an IoT-enabled 'smart meter' allows real time collection of energy produced by remote power stations. AI, applied to verifying results, brings new insights (e.g. assuring the smart meter is not tampered with). This can also be achieved by automatically 'comparing' PV-production results with plants close-by, referencing today's results with last year's, and/or adding local weather data for plausibility.
- MRV advantages translate into advantages for both, measuring negative impact (e.g. emissions as part of carbon pricing) as well as for positive impact (e.g. consumer recycling behaviour)[41].
- 'ESG' (Environmental, Social & Governance performance factors), for the public and the private sector, can be seen as entering the mainstream[42]. Comprehensive ESG/MRV activities will increasingly be a part of standard business practices. Regulators and business partners will expect an increasing amount of data. MRV will translate from a 'necessary evil' to a 'strategic must'. With data generally becoming a more and more important driver of success, MRV will continually gain weight as a core strategic activity, rather than one of mere necessary reporting. Its deployment will yield to more and better data for climate, - and in many other areas as well.
- Distributed solutions allow organisations to 'share' data and dynamically interlink to MRV systems of others[43]. In well-designed systems, individual participants remain in control of their data and at the same time can contribute to thriving data-ecosystems with their stakeholders (including, for example, supply-chain cross border issues involving government and business).

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[38] https://en.wikipedia.org/wiki/Digital_image_processing

[39] Exemplary source: 'Remote Sensing: The Technology, Current Use and Future Outlook', Spudsmart (04/06/2018), https://bit.ly/2OTmyF0

[40] Exemplary source: 'Measuring, Reporting and Verification (MRV) of greenhouse gas (GHG) mitigation', OECD (accessed 20/10/2018), https://bit.ly/2qeowkn

[41] Exemplary source: 'Transparency in Global Environmental Governance', Earth Systems Governance (07/2014), https://bit.ly/2SrR1Iv

[42] Exemplary source: 'Sustainable Investing is Moving Mainstream', JP Morgan (20/04/2018), https://bit.ly/2RjPoes

[43] Exemplary source: 'Sharing Supply Chain Data in the Digital Area', MIT Sloan (15/09/2015), https://bit.ly/2CNRG1d

- Combined with mobile internet access and smart phones, MRV activities can engage all stakeholders, including those in the 'last mile'[44]. A farmer, for example, can play a part in forest monitoring (e.g. taking pictures of relevant forest sections or individual trees in regular intervals).
- Smart phones can be equipped with specialised additional hardware (e.g. for soil or water measurement)[45]. Complex measurement tasks can thereby be 'distributed' to many agents taking measurements. This may result in better overall data as well as new streams of income.
- In climate-related areas, MRV activities will need to start to include the certification of technical measurement equipment as well as other more 'technical/data-driven' quality standards[46].
- New data-sharing revenue models emerge[47]. Different stakeholders share different data sources over marketplaces, where humans and machines buy this data in order to make better decisions.

6. Conclusion

In order to assure fast climate action, public and private sector stakeholders should embrace the opportunities made available by the forth industrial revolution. They should share knowhow and best practices and learn mutually[48]. Key in this process is cooperation on early, specific use case projects that allow all actors to gain first-hand experience[49]. As always when it comes to the implementation of cutting-edge technologies, there will be implementation difficulties, as the devil truly is in the details here. However, the incredible potential of digital MRV through its trust and incentive advantages, seem to far outweigh the transition costs and risks involved.

Image: #Hack4Climate, final presentations at COP23 raising awareness on the innovation potential of IoT, DLT, and AI

[44] Exemplary source: 'ICT in Facilitating Last Mile Services', CRI (26/06/2014), https://bit.ly/2zaARKJ
[45] Exemplary source: Elsevier (02/03/2017), https://bit.ly/2lFcYlE
[46] Exemplary source: Gold Standard Foundation (CLI member, accessed 20/10/2018), https://bit.ly/2yBUxYu
[47] Exemplary source: AIG (Data Sharing Economy Report Part 3), https://bit.ly/2D9T3Ws
[48] CLI has set its focus on understanding the governance implications and research tasks at the intersection of DLT and climate. It first organized stakeholder workshops in 2016, held a joint awareness effort with the UNFCCC secretariat in 05/2017, and now offers capacity building workshops to public and private stakeholders.
[49] As, for example, is attempted with the #Hack4Climate Innovation Program, www.hack4climate.org