Data center and the city:
A potential for urban synergies.

Cristina Ramos Cáceres[1], Marcus Sandberg[2], Adolfo Sotoca[3]

[1]*PhD student in Architecture at LTU, cristina.ramos.caceres@ltu.se*
[2]*Associate professor in Construction Management and Building Technology at LTU, marcus.sandberg@ltu.se*
[3]*Professor, Chaired professor in Architecture at LTU, adolfo.sotoca@ltu.se*

Abstract: The investment landscape for the data center (DC) industry in Europe is currently under transformation, as more DC companies are getting established in the Scandinavian countries; but still the DC surface and power capacity (m² and MW) in these regions has not yet capitalized in the same way as DC traditional locations in central Europe. Nevertheless, the renewable energy as hydropower and a favorable climate for free air cooling that are provided in the North, particularly northern Sweden, among other reasons, are increasingly attracting DC companies seeking to meet their environmental goals at the lowest cost. However, this raises questions on how the land (m²) and energy (MW) demand for new DCs can be met with equity in the local context. While some governments facilitate land management procedures to build new DC facilities and lower the energy tax in order to attract more investors, there has been little attention on how these strategies could support or hinder potential energy synergies with potential social value within the local community (e.g. reuse of DC waste-heat for urban farming). The potential transition that Sweden is facing, due to the DC-phenomenon, becomes a relevant context to investigate alternatives of how to improve urban metabolism's efficiency, in relation with an emerging energy intensive industry; The Data Center industry. The purpose of this research is to investigate how urban planning theory can assist the DC-phenomenon in transitioning towards a circular approach.

Keywords: Circular cities; Multifunctional data center district; Sustainable urban metabolism; Urban planning strategies.

Introduction

Since the establishment of Facebook in Luleå in the north of Sweden, back in 2011, the region's focus in developing strategies to attract Data center companies has increased. These strategies are among others: reduced energy tax, accessibility of cheap land, low time-to-market (Christensen *et al.*, 2018). Some reports state that Facebook has been perceived as a trigger for structural change and economic growth in these northern regions, having had positive effects as: e.g. regional co-location benefits, shared quality workforce, job creation etc. (Ylinenpää, 2014).

However, Sweden and particularly its northern regions are not a traditional location for the data center industry in comparison with the FLAP-D regions in central Europe (Frankfurt, London, Amsterdam, Paris and Dublin). These northern regions have had another industrial tradition based on mainly mining, metallurgy, and forestry (pulp and paper) activities. Despite this tradition, the Nordics and particularly Northern Sweden is facing an industrial transition from a dominant resource extractive strategy to a diversified resource investment strategy (Reffell, 2018). This is partly due to the emerging industry of data centers in the last decade, which has been attracted by tailored economic incentives and environmental assets; in order to balance their high-energy demand with high efficiency standards and greener footprint at the lowest cost (Kontzer T., 2013). However, the Data center industry remains inefficient, as only a small part of the energy is used to store and process data, and the rest of the energy becomes waste-heat. Consequently, there is a recognized need to make data centers more energy-efficient (Summers, 2018).

The described transitional phase that the Swedish industrial system is facing, can be suitable to introduce new paradigms as; *Circular cities*. Introducing possible synergies through a circular approach in the

current industrial linear system can contribute to the DC's need and responsibility to be highly efficient; not only by designing efficient DC facilities but also by defining strategies to locate the DC close to users interested in reusing the high amount of waste-heat they produce. This, since the waste-heat is low grade and airborne and therefore inefficient to transport (Sandberg *et al.*, 2017).

The "city" can be defined as a "platform" enabling material and energy exchange between industries (Rosales Carreón and Worrell, 2018). Urban metabolism theory (Ferrão and Fernandez, 2013) describes how materials and energy flow in a city. The DC sector gives high attention to the energy flows, as energy efficiency is one of their main concerns when establishing a new DC. To achieve maximum efficiency it is essential to measure the amount of energy flowing through the system and the quality of these energy flows (Rosales Carreón and Worrell, 2018). In fact, higher efficiency can be achieved not only with the "right" design of the DC building, but also by choosing the "right" location.

Problem framing

Sweden has had several turning points that led the country into industrial transition periods, as for example the one in the beginning of the twentieth century with the invention of the electricity networks by Edison in 1879 and three-phase technology by Jonas Wenström in 1890; solving the distribution of electricity in long distances (Vattenfall, 2019). This enabled industries, which initially were powered by waterwheels and local small hydropower stations to settle closer to cities, far from the energy source (watercourse), where users and other services were located. Nowadays, Sweden would face a similar challenge within the context of the emerging DC industry transitioning towards a circular approach, where the DC's are energy (waste-heat) producers and have issues to transport the energy (heat) over long distances efficiently to be used by other sectors/ industries. The current situation of inefficient energy use in the DC sector leads to reconsider, from the sustainable urban metabolism perspective, the location of local industries/activities closer to the heat producer (DC), and vice versa, in order to able to use the energy (electricity) in a more efficient way minimizing waste (waste-heat).

The DC sector need to consider a more efficient energy management (e.g. minimizing waste-heat), in order to tackle efficiency with a more holistic perspective (including social, environmental and economic factors). This would mean changing the perception of DCs from only energy consumers to partly energy producers of waste-heat (prosumers). There are several examples of waste-heat reuse from DC for other activities integrated in the DC building as: swimming pool (Brodkin, 2008), greenhouse (Miller, 2008), housing and non-housing buildings (Miller, 2009), desalination plant (Sverdlik, 2014) and fish farm (Verge, 2015). Nevertheless, these are exceptional cases, which are not the rule; still the concept of "waste-heat reuse" has not yet been introduced as a routine when establishing new DCs. This paper does not focus on analyzing the technological development of this possible integration between the DC and other activities, but does focus on describing and analyzing the events and factors that are currently enabling or disabling, this integration, taking as a case study northern Sweden (the counties of Norrbotten and Västerbotten).

Research approach

Case study methodology was the one chosen for this study as it allows highlighting the details on the DC phenomenon, from the stakeholder's perspective, by using multiple sources of data as evidence (Tellis, 1997). A major strength of having chosen case study's data collection methods is the opportunity to use different sources of evidence, allowing addressing a range of historical, attitudinal and behavioral issues. Most importantly, it allowed the development of a converging line of investigation, "any finding is likely to be more accurate and convincing if based on several sources of information", (Yin, 2013). Two data collection methods were chosen in this qualitative research approach: unstructured/open-ended interviews and literature review. Unstructured interviews, as an inductive method of data gathering, enabled to discover experiences and knowledge from the interviewees, which had not been taken in consideration before; "When researchers are more interested in knowing greater details about a phenomenon, unstructured questions may aptly accomplish those aims", (Firmin, 2012). These interviews followed the two simultaneous levels of operation required: the need to follow the line of investigation while at the same time asking questions as open as possible, in a friendly and non-threatening manner (Yin, 2013).

The research was approached: firstly, as an *Exploratory framework*; finding which stakeholders are involved in the DC phenomenon events (who) and in what part of the process (Yin, 2013). Secondly, as an *Explanatory case study*; focusing on the why and how these stakeholders were involved in each event (Yin, 2013) (e.g. tailored strategies, site-selection criteria, establishment process, research and development...etc.), in the context of northern Sweden.

The interviewees are national, regional and municipal key actors involved directly or indirectly in the DC-industry development (Table 1). Interviewees were selected after doing a literature review and identifying key actors inside private/public bodies involved in DC-establishment in the region. Some of the conducted interviews led to the contact of other key actors for following interviews (e.g. interview with stakeholder A, led to interview with stakeholder C). All the interviews were done face to face in arranged meetings.

*	Interviewee	date	stakeholder type	interview type
	stakeholder A	18/03/2019	Regional actor	unstructured/ open-ended
	stakeholder B	26/03/2019	Data Center company	unstructured/ open-ended
	stakeholder C	05/04/2019	Regional actor	unstructured/ open-ended
	stakeholder D	24/04/2019	National actor	unstructured/ open-ended
	stakeholder E	29/04/2019	Data center company	unstructured/ open-ended
	stakeholder F	22/05/2019	Data Center company	unstructured/ open-ended
	stakeholder G	29/05/2019	Regional actor	unstructured/ open-ended

Table 1: Table of interviews conducted in the case study

Literature review is used as a qualitative research method in this study; as it serves as a tool for data collection and data analysis (Onwuegbuzie and Frels, 2017). As the purpose of this research was to see how urban planning theory can assist the DC-phenomenon in transitioning towards a circular approach, the two main topics selected to search upon were “Urban planning” and “Data center”; identifying subcategories that support the circular approach, as an inclusion criteria. These subcategories were used as key words in the retrieval process of the documents analyzed.

Table 2 shows the main topics relevant for the research divided up in three groups, with subcategories: Urban planning (Circular cities, Urban metabolism system, Urban sustainability); Data center (DC Waste-heat reuse, DC Business trend, DC Energy, DC Sustainability) and a third group where Data center and Urban planning topics are related.

Main topics	Topic subcategories	Scientific Articles	Reports	Books	News Articles	Websites	References
Urban Planning [UP]	Circular cities	2	1				(Kirchherr,2017); (Williams, 2018); (Kalmykova et al.2016)
	Urban metabolism system	5	1	1		1	(Kennedy et al,2011); (Prendeville, 2018); (Jackson et al.,2010); (Business Index North, 2017); (Barles, 2010);(Vattenfall, 2018); (Dijst, 2018)(Ferrão & Fernandez, 2013)
	Urban Sustainability	6			2		(Brito and Burke, 2008); (Rosales-Carreón,2018); (Andrén,2009); (Gonzalez-Garcia, 2018); (Heinz-Hebert, 2002); (Cinelli et al. 2014); (Grova and Reith, 2013); (Sala et al.,2015)
Data Center [DC]	DC Waste-heat reuse	1	2		6		(Wahlroos et al., 2018); (Brodkin, 2008); (Miller, 2008); (Miller, 2009); (Sverdlik, 2014); (Verge, 2015); (Patterson, 2010); (Tschudi, 2010);(Biba, 2017)
	DC Business trend		1		3		(Warrestein et al.,2016); (Christensen et al., 2018); (Digiplex, 2018); (Reffell, 2018)
	DC Energy		5		1	1	(Nelson, 2017); (Avgerinou et al.,2017); (tgg,2007); (Danilak, 2017); (Summers, 2018); (Avelar et al., 2012); (Garris, 2018)
	DC Sustainability	1	3		1		(Henriksson, 2017); (Lykou et al.,2018); (Cowi, 2018); (Ylinenpää, 2014); (Cremer, 2018)
UP + DC			1		1	1	(Sergejev, 2015);(Juvalainen, 2016); (Biba, 2017)

Table 2: Documents analyzed in the literature review method

Results

As a consequence of the interviews and literature review methods, a timeline (Figure 1) was created with the aim to understand historical (national/ regional/ municipal) chain of events that contributed to the DC establishment in Swedish northern regions and find traces of strategies, initiatives or attempts that impacted DC synergies within the local context. The timeline shown in Figure 1 was drawn by information retrieved mainly from literature review and the conducted interviews.

The result is a composition of relevant highlights in the DC-phenomenon's history, that enables a longitudinal analysis between different events along a timeline. (e.g. energy tax reduction, successful and unsuccessful synergy attempts, national renewable energy history, business trends, industrial transition...)

The timeline structure was built through Lefebvre's lens, describing a phenomenon divided up in three different periods; construction period, consolidation period and decline period (Lefebvre, 1975). The scope of the study focuses in the description and analysis of the construction and consolidation period of the DC-phenomenon as the decline period has not occurred in northern Sweden context at the time.

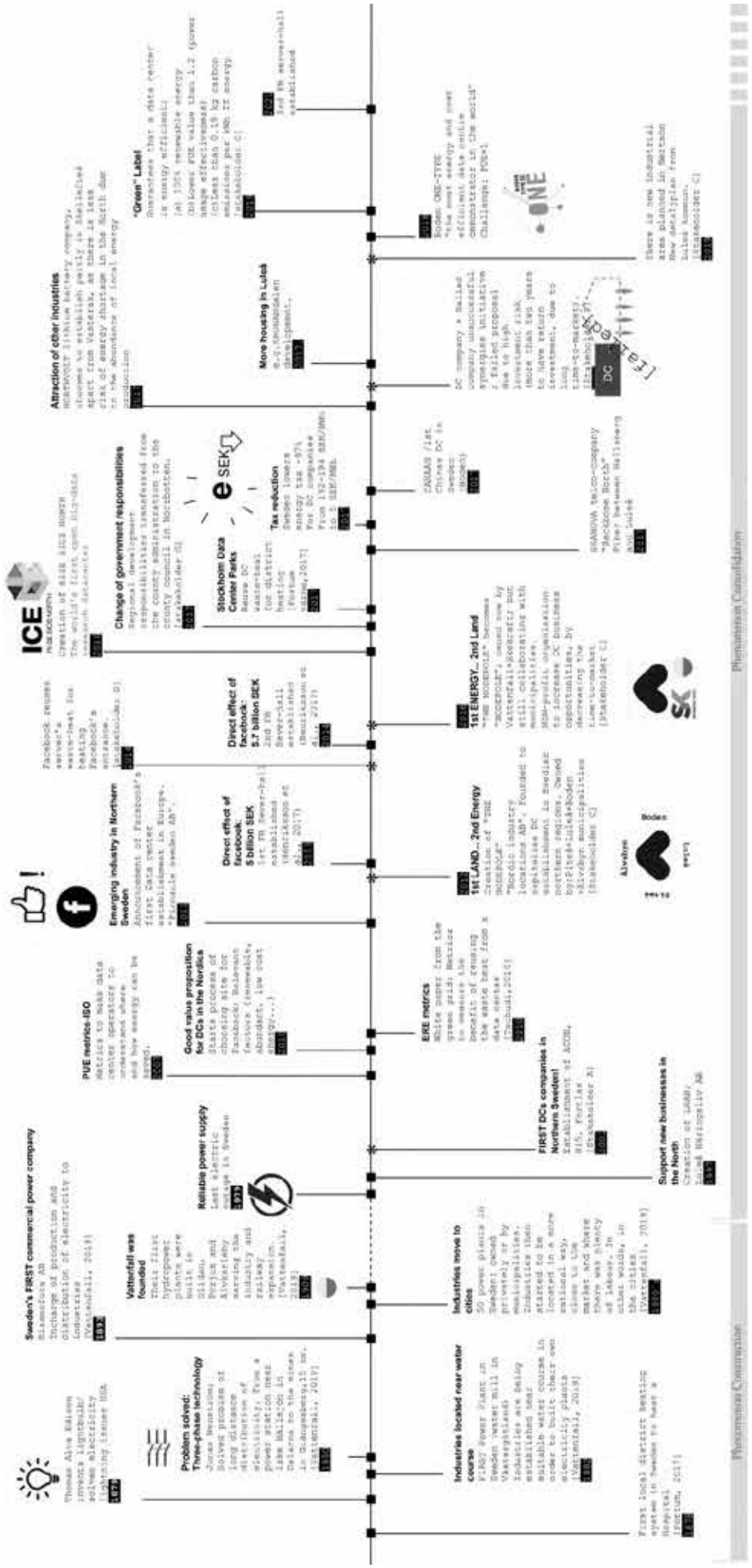

Figure 1: Timeline of the event highlights in relation with the DC-phenomenon in Northern Sweden

Discussion of the results

The DC sector has an interest in establishing in the North, as strategies are tailored to fit their needs in relation to their economic and environmental challenges. As shown in Figure 1 in 2017 there was an unsuccessful attempt in doing synergies; a data center company and a greenhouse vegetable producer built a consortium to reuse the DC waste-heat, but the plan was not realized, as the lack of available electrical power in the location chosen would increase the time-to-market, carrying an investment risk. "Most European data center owners/managers don't want to commit capital funds to an energy-reduction tactic if the full return on investment isn't realized in less than two year", (Garris, 2018). This initiative could have had the potential of being successful if other priorities than economic factors would have been taken into account, by analyzing the value of waste-heat through different cost-opportunity scenario giving special attention to some social and environmental questions: How many jobs would this create? Would this improve the DC company's Corporate Social Responsibility? How would this contribute to the development of other vulnerable sectors in these regions (e.g. horticulture)?

Regional development strategies should be designed with a more holistic perspective, including not only how the DC sector could contribute economically to the regions development but how could it contribute socially as well. DC-phenomenon is a global economic activity gathering in regional clusters (Sassen, 2002) as in the case of the traditional DC clusters in central Europe and as well as in the case of the emerging DC cluster in the Nordics, where the government has a high risk in losing the holistic perspective when creating new policies (e.g. energy tax reduction) pressured by the urge to become competitive in the global DC market. The county council (e.g. Region Norrbotten) in collaboration with the county administration could be given a higher responsibility in serving the local community by enhancing measures that contribute to both social and economic development. Hence, research on how the DC-sector can be better integrated through synergic models inside the national and regional economic system is of high interest for the national and regional governments. There is a need to do more investigations on the possible different synergic scenarios and display the cost-opportunity in relation with the three sustainability aspects; economic, environmental and especially social.

Nowadays, the majority of DCs in the north do not gain any benefit with the waste-heat, therefore it is valuable to consider the opportunities to gain economic benefit while at the same time fulfilling their responsibility of giving back the benefit to the local community (e.g. food self-sufficiency), as this is not done through the energy tax currently. Since 2017, the state subsidized the DC sector with a tax reduction of 97% (Henriksson *et al.*, 2017), playing an important role in the DC-phenomenon attracting DC not just by the renewable and reliable power supply but by the low energy cost. However, this strategy can make the DC investment vulnerable in the long run, for example, future droughts in these regions due to climate change can question the legitimacy of these incentives in the case of future energy shortage. This arises questions as; Is it legitimate to give subsidies to a highly inefficient DC-industry, as more than half of the energy consumed is converted in waste-heat? Should the state give subsidies instead to DC that want to make use of the waste-heat? How can urban planning strategies support then the national/regional strategies in this endeavor?

Meanwhile, some initiatives of DC waste-heat reuse have been successfully implemented, among other countries (US, Canada, Finland), in Sweden, specifically in the South in the city of Stockholm, by planning Data Parks inside the city where the waste-heat is collected, directed inside a PowerStation and plugged into the district heating network, however, this model is not infinitely scalable (Biba, 2017). In fact, there could be challenges to implement this model in Northern Sweden nowadays, as there is already energy surplus due to the waste-heat from the traditional energy intensive industry (metallurgy, pulp and paper) which the district heating network would not need to absorb. Therefore, there is a need to investigate how these "Data Parks" can be not just a cluster of DCs but instead DC integrated with other local sectors/activities in need of the DC waste-heat. Creating multifunctional-DC districts that can re-use the waste-heat directly in a more efficient way could be an alternative, instead of plugging it into the district heating network, which is a process that is currently inefficient, as it requires additional energy to do it (Biba, 2017).

Despite, the effort of some municipalities in Sweden to reuse the DC waste-heat there is a mismatch with some strategies taken in some institutions working at the national level. A "green" label was created in 2019, as shown in Figure 1, in order to encourage the DC companies to have environmental friendly and energy efficient facilities.

This label measures efficiency through the Power Usage Effectiveness (PUE) metrics, which considers the efficient design of the DC building but does not include the Energy Reuse Effectiveness factor (ERE metrics), which measures the amount of waste heat reuse. Another example of mismatch is the development in 2018 of, potentially, the most efficient DC-prototype in the world, located in northern Sweden, Boden, which did not include reuse of waste heat. Even, the development process of the most efficient datacenter in the world could be improved by not only focusing in just PUE metrics, but as well considering ERE metrics (energy reuse metrics) in order to give a more complete view of DC-efficiency and utilizing its full potential. Hence, there is a need to synchronize the top-bottom national strategies with the bottom-up initiatives from municipalities, as in the case of Stockholm being a reference of good practice, in order to encourage municipalities to integrate the DCs in a more efficient and sustainable way inside the city.

Conclusions

Many other countries in the world, like Sweden, are facing changes in its urban metabolism as a consequence of the emerging data center industry. There is a competition for resource investment within each country, among the emerging DC-industry and the already existing industries/sectors. Tailored initiatives as energy tax reduction for the DC industry should be reconsidered, as future scenarios of energy shortage (NordBER, 2015) could question the legitimacy of these economic incentives. The DC industry still has technical challenges on how to reuse the waste-heat since the waste-heat, which is low grade, airborne and therefore hard to transport (Sandberg et al., 2017). There is a need to improve the way efficiency is tackled inside the urban metabolism energy system in regards to the DC sector. These improvements could be done at two levels: first, at a technical level; by considering ERE metrics (Energy Reuse metrics) instead of solely PUE metrics when creating "green labels" as a national strategy to attract DC investors in Sweden as this circular approach contributes to having a complete view of efficiency. This way DC companies have the possibility to design efficient buildings but as well elect a better location in order to minimize energy waste. And secondly, at a policy level: in the case of northern Sweden, the emerging energy intensive sector as DC could support vulnerable sectors, as for example horticulture, in need of heat for greenhouse vegetable production, in order to cope with the cold climate. It is worth considering local community benefits rather than just the national weight gain on global market, by prioritizing synergies with local activities/ sectors that have the highest need in reusing the DC waste-heat. This can contribute to solve sustainable urban development issues (Barles, 2010), as for example, risk of food scarcity, especially in Northern regions where the subarctic climate makes agriculture become energy demanding (need of light and heat). Creating multifunctional-DC districts inside the city, where diverse activities in need of DC waste-heat can be integrated together with the DC building, in order to re-use the waste-heat directly, could be an alternative to current inefficient strategies.

Acknowledgement
This study is part of the Cloudberry project—Multifunctional datacenter. The authors would like to thank the Swedish Energy Agency for funding the study.

References

Andrén, S. (2009) *Urban sustainable development from a place-based and a system-based approach: Case study Malmö*. Available at: http://www.hek.lu.se (Accessed: 1 February 2019).

Avelar, V. *et al.* (2012) 'PUE ™ : A COMPREHENSIVE EXAMINATION OF THE METRIC'.

Avgerinou, M., Bertoldi, P. and Castellazzi, L. (2017) 'Trends in Data Centre Energy Consumption under the European Code of Conduct for Data Centre Energy Efficiency', *Energies*, 10(10). doi: 10.3390/en10101470.

Barles, S. (2010) 'Society , energy and materials : the contribution of urban metabolism studies to sustainable urban development issues', 0568(May). doi: 10.1080/09640561003703772.

Biba, E. (2017) *The city where the internet warms people's homes*, *Ecological Applications*. Available at: http://www.bbc.com/future/story/20171013-where-data-centres-store-info---and-heat-homes.

Brits, A. and Burke, M. I. (2008) 'Towards an Urban Sustainability Assessment Framework : Supporting Public Towards an Urban Sustainability Assessment Framework : Supporting Public Deliberation around Sustainability of Specific Contexts', (July 2014).

Brodkin, J. (2008) *Swimming pool heated by data center's excess heat | Network World*. Available at: https://www.networkworld.com/article/2277915/data-center/swimming-pool-heated-by-data-center-s-excess-heat.html (Accessed: 31 January 2019).

Christensen, J. D. *et al.* (2018) *Data centre opportunities in the Nordics: An analysis of the competitive advantages*. Copenhagen K. doi: 10.6027/TN2018-553.

Cinelli, M., Coles, S. R. and Kirwan, K. (2014) 'Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment', *Ecological Indicators*. Elsevier, 46, pp. 138–148. doi: 10.1016/J.ECOLIND.2014.06.011.

Cowi (2018) *TEMAANALYSE OM STORE DATACENTRE*. Available at: https://ens.dk/sites/ens.dk/files/Analyser/temaanalyse_om_store_datacentre.pdf (Accessed: 24 January 2019).

Cremer, J. (2018) *The climate-friendly tech trend sweeping Sweden - The Local*. Available at: https://www.thelocal.se/20181221/the-climate-friendly-tech-trend-sweeping-sweden-dcbs-tlccu (Accessed: 10 January 2019).

Digiplex (2018) *A Perfect Storm: Data Centre Trends 2018*.

Dijst, M. *et al.* (2018) 'Exploring urban metabolism—Towards an interdisciplinary perspective', *Resources, Conservation and Recycling*. Elsevier, 132, pp. 190–203. doi: 10.1016/J.RESCONREC.2017.09.014.

Ferrão, P. and Fernandez, J. (2013) *Sustainable urban metabolism*. Available at: https://libris-kb-se.proxy.lib.ltu.se/export.jsp?type=showrecord&q=onr%3A15157533&id=15157533&d=libris&posts=1 (Accessed: 31 May 2019).

Firmin, M. W. (2012) 'Unstructured Interview'.

Garris, L. (2018) 'The Current State of Data Center Energy Efficiency in Europe'.

Gonzalez-García, S. (2018) 'Assesing the sustainability of spanish cities considering environmental and socio-economic indicators'. Available at: https://ac.els-cdn.com/S0959652618300647/1-s2.0-S0959652618300647-main.pdf?_tid=d07a63f9-9378-45ce-ad30-9964092a900e&acdnat=1550135532_4b126f51ad3faa52dc561476900b9b29 (Accessed: 14 February 2019).

Heinz-Hebert, N. (2002) *TOWARDS A EUROPEAN SYSTEM OF SOCIAL INDICATORS: THEORETICAL FRAMEWORK AND SYSTEM ARCHITECTURE*. Available at: https://link.springer.com/content/pdf/10.1023%2FA%3A1015775631413.pdf (Accessed: 10 December 2018).

Henriksson, J. *et al.* (2017) *Effekter av Facebooks etablering i Luleå*.

Jackson, S., Hitchins, D. and Eisner, H. (2010) 'What Is the Systems Approach?', *Insight*, 13(1), pp. 41–43. doi: 10.1002/inst.201013141a.

Juvalainen, J. (2016) *Initial Business Concept for the neighborhood data center*. Helsinki. Available at: http://www.theseus.fi/bitstream/handle/10024/110299/Juvalainen_Jyri.pdf?sequence=1&isAllowed=y (Accessed: 31 January 2019).

Kalmykova, Y. and Rosado, L. (2016) *Urban Metabolism as Framework for Circular Economy Design for Cities*. Available at: http://publications.lib.chalmers.se/records/fulltext/232085/local_232085.pdf (Accessed: 8 January 2019).

Kennedy, C., Pincetl, S. and Bunje, P. (2011) 'The study of urban metabolism and its applications to urban planning and design', *Environmental Pollution*. Elsevier, 159(8–9), pp. 1965–1973. doi: 10.1016/J.ENVPOL.2010.10.022.

Kirchherr, J., Reike, D. and Hekkert, M. (2017) 'Conceptualizing the circular economy: An analysis of 114 definitions', *Resources, Conservation and Recycling*. Elsevier, 127, pp. 221–232. doi: 10.1016/J.RESCONREC.2017.09.005.

Lefebvre, H. (1975) 'L'État dans le monde moderne', in *L Homme et la société*. Persée - Portail des revues scientifiques en SHS, pp. 3–23. doi: 10.3406/homso.1975.1596.

Lykou, G., Mentzelioti, D. and Gritzalis, D. (2018) 'A new methodology toward effectively assessing data center sustainability', *Computers & Security*. Elsevier Advanced Technology, 76, pp. 327–340. doi: 10.1016/J.COSE.2017.12.008.

Miller, rich (2008) *Data Center Heats a Greenhouse | Data Center Knowledge*. Available at: https://www.datacenterknowledge.com/archives/2008/05/16/data-center-heats-a-greenhouse (Accessed: 31 January 2019).

Nelson, D. (2017) *DATA CENTER PERFORMANCE INDEX*.

NordBER (2015) *Energy shortage*.

Onwuegbuzie, A. J. and Frels, R. (2017) *Seven Steps to a Comprehensive Literature Review: A Mutimodal and Cultural Approach*. doi: 10.1177/0971890717701780.

Orova, M. and Reith, A. (2013) *Comparison and evaluation of neighbourhood sustainability assessment systems*. Available at: https://mediatum.ub.tum.de/doc/1169262/1169262.pdf (Accessed: 18 February 2019).

Patterson, M. (2010) *EDITOR: ERE: A METRIC FOR MEASURING THE BENEFIT OF REUSE ENERGY FROM A DATA CENTER EXECUTIVE SUMMARY*. Available at: https://eehpcwg.llnl.gov/documents/infra/06_energyreuseefficiencymetric.pdf (Accessed: 30 April 2019).

Prendeville, S., Cherim, E. and Bocken, N. (2018) 'Circular Cities: Mapping Six Cities in Transition', *Environmental Innovation and Societal Transitions*, 26, pp. 171–194. doi: 10.1016/j.eist.2017.03.002.

Reffell, C. (2018) *Iron and Steel Give Way to Data Centres as the Capital of Northern Sweden Transforms to a Sustainable Future - Crowdsourcing Week*. Available at: https://crowdsourcingweek.com/blog/iron-steel-give-way-to-datacentre-sustainable-future-sweden/ (Accessed: 31 May 2019).

Rosales Carreón, J. and Worrell, E. (2018) 'Urban energy systems within the transition to sustainable development. A research agenda for urban metabolism', *Resources, Conservation and Recycling*, 132, pp. 258–266. doi: 10.1016/j.resconrec.2017.08.004.

Sala, S., Ciuffo, B. and Nijkamp, P. (2015) 'A systemic framework for sustainability assessment', *Ecological Economics*. Elsevier, 119, pp. 314–325. doi: 10.1016/J.ECOLECON.2015.09.015.

Sandberg, M. *et al.* (2017) 'A modelling methodology for assessing use of datacenter waste heat in greenhouses'. Available at: https://pdfs.semanticscholar.org/5922/fca22e84ab42a1d20ffe19b45a9e626d2579.pdf (Accessed: 31 May 2019).

Sassen, S. (2002) 'Environment and Urbanization Locating cities on global circuits', 14(1), pp. 13–30. doi: 10.1177/095624780201400102.

Sergejev, I., Rünkla, I. and Jakobs, T. (2015) *Project Rhizome*. Available at: http://project-rhizome.com/ (Accessed: 31 May 2019).

Summers, J. (2018) *"Data centre is the light bulb of the 21st century" - Luleå University of Technology*. Available at: https://www.ltu.se/research/subjects/Stromningslara/Nyheter-och-aktuellt/Datacenter-ar-2000-talets-glodlampa-1.182421?l=en (Accessed: 6 December 2018).

Sverdlik, Y. (2014) *Desalination Plant and Data Center: Not as Odd a Couple as May Seem | Data Center Knowledge*. Available at: https://www.datacenterknowledge.com/archives/2014/08/25/a-desalination-plant-and-a-data-center-not-as-odd-of-a-couple-as-it-may-seem (Accessed: 31 January 2019).

Tellis, W. M. (1997) 'Application of a Case Study Methodology Application of a Case Study Methodology', 3(3), pp. 1–19.

Tschudi, B. *et al.* (2010) *ERE : A METRIC FOR MEASURING THE BENEFIT OF REUSE ENERGY FROM A DATA CENTER*.

Verge, J. (2015) *Proposed Fish Farm Would Tap Data Center Waste Heat | Data Center Knowledge*. Available at: https://www.datacenterknowledge.com/archives/2015/06/05/project-seeks-combine-sustainable-fish-farm-data-center (Accessed: 31 January 2019).

Wahlroos, M. *et al.* (2018) 'Future views on waste heat utilization – Case of data centers in Northern Europe', *Renewable and Sustainable Energy Reviews*. Pergamon, 82, pp. 1749–1764. doi: 10.1016/J.RSER.2017.10.058.

Warrenstein, A. *et al.* (2016) *CAPTURING THE DATA CENTER OPPORTUNITY HOW SWEDEN CAN BECOME A GLOBAL FRONT-RUNNER IN DIGITAL INFRASTRUCTURE*. Available at: https://www.business-sweden.se/contentassets/b0cf679fdc2247bf8bb9653d7ec11013/bcg-capturing-the-data-center-opportunity-june-2016.pdf (Accessed: 11 March 2019).

Williams, J. (2018) 'Circular cities'. doi: 10.1177/0042098018806133.

Ylinenpää, H. (2014) *Etableringen av Facebooks europeiska datacenter i Sverige och Luleå*. Available at: https://tillvaxtverket.se/download/18.c0b0f00158b992593dce81/1480675502044/Etableringen_av_Facebooks_europeiska_datacenter.pdf (Accessed: 14 May 2019).

Vattenfall. The revolution of electricity (History before Vattenfall), Available at: https://history.vattenfall.com/the-revolution-of-electricity/before-vattenfall (Accessed: 16 May 2019).

Rethinking organic waste streams as metabolic drivers for improving urban sustainability and agroecological practices

Sarah Stempfle[1], Chiara Tornaghi[2], Matelda Reho[3]

[1]*Università Iuav di Venezia, Department of Architecture and Art, stempfle@iuav.it*
[2] *Coventry University, Centre for Agroecology, Water and Resilience (CAWR), ac0952@coventry.ac.uk*
[3]*Università Iuav di Venezia, Department of Architecture and Art, matelda@iuav.it*

Abstract: Restoring the nutrient cycles, and assuming their centrality for sustainable management of agro-environmental resources at local level, are key aspects for amending the metabolic rift that has been historically triggered by the emergence of capitalistic socio-spatial organization, and that is currently reproduced and further deepened under neoliberal urbanization processes. This paper aims to explore how organic waste streams can be reorganized and reconnected with urban and periurban agriculture, enabling the proactive role of farmers and food growers in soil nutrient cycling, and reshaping urban metabolism towards more regenerative and resourceful models. In particular, we look at composting practices as meaningful entry points for inquiring the relations between urban metabolism and agroecological practices. The paper builds on some initial insights offered by the case studies of London and Venice, bringing to light which kind of soil nutrition and land management practices are currently prevailing among food growers in these contexts, which connections are established between food production and food waste, to which extent compost from organic waste is valued (and eventually claimed) as an essential asset for nutrient cycling, how access and control on resources can be facilitated and empowered, and finally how the pattern of urban waste streams can be rethought for enabling place-based metabolic ecologies, considering environmental and social justice issues. Unpacking these aspects allows to understand better how metabolic processes are related to (and embedded into) specific practices of labor located in time and place, and to expand the urban metabolism analytical framework in order to move beyond the 'black box' effects from which suffer many quantitative approaches strictly focused on material flows.

Keywords: organic waste, nutrient cycling, resource management, urban metabolism, urban agroecology

Introduction

In this paper we look at ways in which organic waste management, soil keeping, and food production interplay in nutrient cycles, as an entry point to understand and rethink urban metabolism. The inherent unsustainability of the current resource-intensive, exploitative and disposable socio-economic model requires a structural transformation of the ways we provide our basic (and superfluous) needs. The most urgent imperatives we must face are 1) to disrupt the reliance on fossil fuels, and 2) to dismantle the dominant linear paradigm that has been shaping the economic and spatial organization production systems, together with the related urbanization models and the underpinning metabolic processes in the last two centuries, shifting towards circular and