Chapter 17

Every drip counts: Confusion of cause with effect in the climate debate

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17.1 BACKGROUND

The main component of the water cycle has been up to now almost totally ignored: evaporation. As evaporation is responsible for all precipitation, it is a key driver for the global, and as well local, climate. Figure 17.1 shows the energy budget on the surface of the earth as mean of one square meter worldwide. Incoming radiation is converted into four components: (a) reflection and (b) longwave emission, as part of direct radiation components; (c) sensible heat; and (d) evaporation as converted energy components, also summarised as net radiation.

The global energy budget is dominated by evaporation and condensation. While reflection and longwave emissions represent 7% and 38% of incoming shortwave radiation, respectively, the largest component represents evaporation at 43%. Furthermore, evaporation reduces longwave thermal radiation due to the decrease in surface temperatures.

A reduction in evaporation as e.g. result of urbanization processes is shown in Figure 17.2. Urbanization results in huge changes to the small water cycle. While

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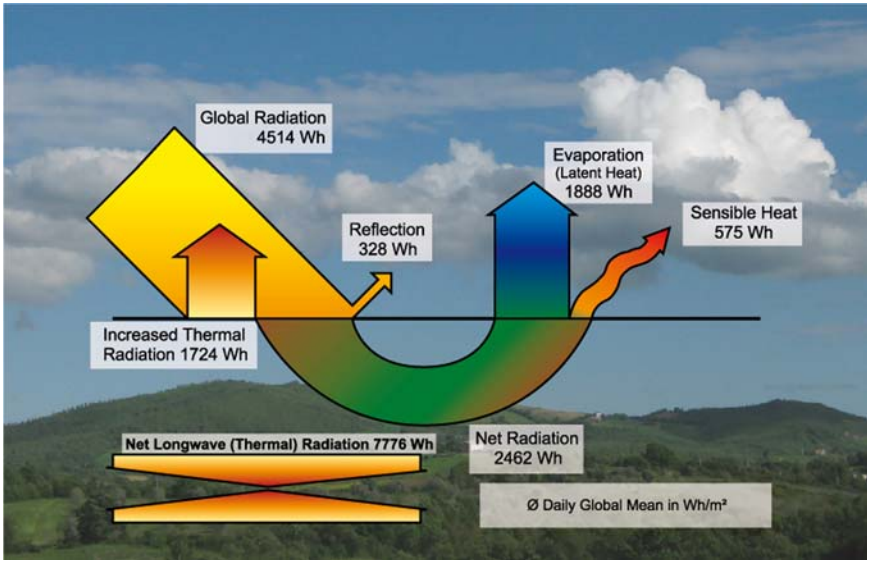

Figure 17.1 Average global daily radiation budget of one square meter worldwide (Schmidt, 2010). Energy data based on www.physicalgeography.net.

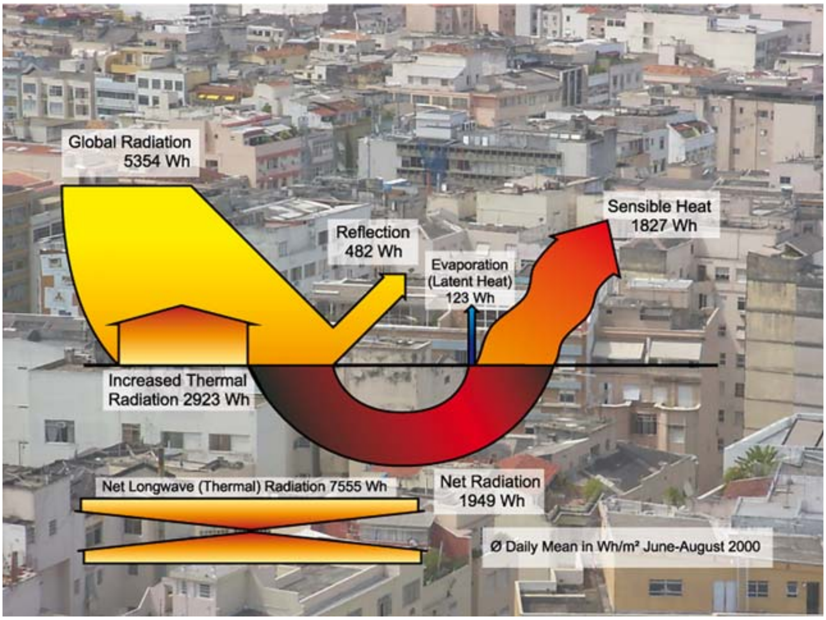

Figure 17.2 Radiation budget of a black asphalt roof as an example for urban radiation changes (Schmidt, 2005).

rainwater is funnelled into sewer systems, surfaces absorb and re-radiate solar irradiation. As a result, air temperatures inside buildings also rise, leading to greater energy consumption from air conditioning. This worsens the situation of the urban heat island effect by a release of additional heat due to the use of electricity for cooling (Schmidt, 2003). To exemplify radiation in urban areas, Figure 17.2 illustrates the radiation budget of a black asphalt roof in the summer months in Berlin. While rainwater disappears into sewer systems, most of the net radiation from the urban setting is converted to sensible heat rather than evaporation. Higher surface temperatures also increase thermal radiation.

The option to green buildings is a logical solution to create healthy and sustainable air temperatures in cities and improve microclimate. Vegetation on and around buildings converts solar radiation into latent heat by evapotranspiration. A further option is rainwater harvesting from roofs and paved surfaces to be used for irrigation. A third option is rainwater use in air conditioners to provide evaporative cooling. This avoids the use of conventional compression cold. While conventional systems are based on the use of electricity and therefore emit heat, evaporation results in real cold and finally precipitation.

While urbanization increases at a global rate of 150 km^2 daily, reduced evaporation results in reduced precipitation and increase in temperatures.

A new water paradigm was established by Kravčík *et al.* (2007). While evaporation in the ‘virtual water’ concept is defined as a loss, after Kravcik it is expressed as source of precipitation. Local precipitation rates are dominated by the small water cycle, evaporation on land and resulting precipitation on land (Figure 17.3).

For the area Berlin/Brandenburg, Germany, a reduction in evaporation of 1 m^3 due to unsustainable land use, results in a reduction of precipitation on land of 5 m^3. In the catchment area of Berlin/Brandenburg, about 80% of precipitation is converted to evaporation, while groundwater recharge and runoff together represent 20%. Urban areas are characterized by completely paved or semi-permeable surfaces with little to no vegetation. Semi-permeable surfaces allow much higher groundwater recharge compared with naturally vegetated areas (Schmidt, 2005), as they over-compensate for infiltration with reference to completely paved surfaces. Therefore, in the interest of effective environmental care taking, the provision for evaporation rather than infiltration needs to become a primary task.

Implementing the new climate paradigm with a focus on evaporation at a local level requires rethinking urban planning and water management infrastructures. With regard to the urban heat island effect and the issue of global warming, urban planners, architects and landscapers need to consider the natural water cycle, including evaporation, condensation and precipitation (Milosovicova, 2010). The conventional management of water discharge, which was implemented for over a hundred years, nowadays bears disastrous environmental

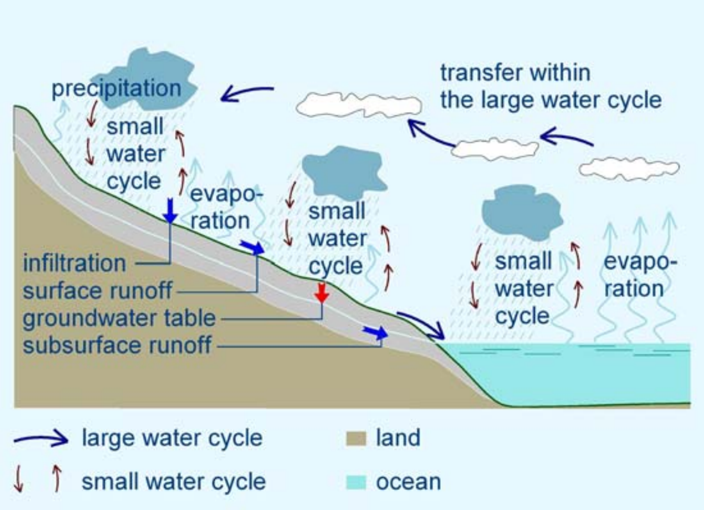

Figure 17.3 Large (ocean–land) and small (land–land and ocean–ocean) water cycles (Kravčík *et al.* 2007).

effects on both surface water quality and on the climate. More recently, rainwater infiltration has been a popular strategy in Germany. However, in spite of the great benefit of preventing negative impacts to surface waters, infiltration does not fully rectify the natural water cycle. Urban areas are not characterized by reduced infiltration rates (SenStadt, 2013). The missing hydrological component is evaporation.

Through urban design strategies such as green facades, green roofs and stormwater ponds, rainwater management strategies play supportive roles as adaptation and mitigation strategies against the urban heat island effect and global warming. By applying the new paradigm small local water cycles are restored (see www.rainforclimate.com). Harvesting rainwater for evaporation should be a first priority in urban areas. Several projects have been established in Berlin with a focus on rainwater harvesting and evaporation, of which two are presented here, Potsdamer Platz and Adlershof Physics Building.

17.2 POTSDAMER PLATZ

A large project supporting the new water paradigm is the former DaimlerChrysler-Area at Potsdamer Platz in Berlin (https://potsdamerplatz.de/en/sustainability/). From 1996–1998 the largest construction site in Europe was built under very strict stormwater management regulations. In order to avoid overloading the existing combined sewerage system in central Berlin, the building permit issued by city council stated that the new complex would drain runoff at a rate of no more than 3 l/sec/ha, or 1% of flows during storm events. To comply with this regulation, the Atelier Dreiseitl (www.dreiseitl.com) and landscape architect Daniel Roehr in cooperation with Technische Universität Berlin implemented the following techniques for the management of 23 000 m^3 precipitation which falls annually on this building site:

- extensive and intensive green roofs on all of the 19 buildings;
- collection of roof runoff for toilet flushing and plant irrigation;
- an artificial lake for rainwater retention and evaporation.

Since infiltration was not possible at this site, the basis for the rainwater management concept involved rainwater harvesting for toilet flushing and evaporation by green roofs and an urban lake as a retention pond. Three cisterns providing 2550 m^3 storage capacity correspond directly to 12% of the annual precipitation of the catchment area. The artificial lake (Figure 17.4), covering a total area of 13,000 m^2, can fluctuate its levels by 30 cm, which corresponds to an additional storage capacity of 11% of the annual precipitation. The water is cleaned and filtered through artificial filtering systems and additionally by a constructed wetland of 1900 m^2 which is planted mainly with Phragmites. The resulting water quality, as well as stormwater issues, has proven that this large rainwater system has performed very well for the last 20 years of operation.

Figure 17.4 Urban lake, supplied with roof-runoff at Potsdamer Platz. (*Source*: Author's own).

17.3 ADLERSHOF PHYSICS BUILDING

Another innovative project providing the new climate and water paradigm on evaporation is the Institute of Physics in Berlin-Adlershof (Figure 17.5). The building is located in a research and office facility featuring several measures of sustainable architecture. It was designed by the architects Georg Augustin and Ute Frank (Berlin) following an architectural competition held in 1997. Rainwater is used to supply a façade greening system and central air-conditioning systems with evaporative exhaust air cooling. The water is harvested from the roofs and stored in five cisterns.

Research elaborating on the performance of the building is carried out by Technische Universität Berlin and funded by the Berlin Senate of Urban Development, the Federal Ministry for Science and Technology and the Federal Ministry for Environment. The project includes permanent monitoring of the water consumption of different plant species and eight air conditioning units. Continuous monitoring has been carried out since 2004.

The façade greening system is evaluated to determine the importance of evapotranspiration and shading on the overall energy performance of the building, including temperature and radiation measurements. Data collected from this project is used to calibrate simulations that are designed to predict performance and benefits in range of different climatic conditions. This work will inform the design of future projects (SenStadt, 2010).

About 300 parameters are electronically harvested every minute. Primary systematic evaluation is based on the water parameters and their relation to energy dissipation. Additionally, 20 plant species and their requirements for maintenance (fertilization, plant protection) are monitored. Seven long-wave,

Figure 17.5 Façade greening system (left), artificial rainwater pond combined with trough infiltration for stormwater management (right). (*Source*: Author's own).

short-wave and infrared sensors monitor the radiation concerning shading and reflection for a conventional façade with sunblinds and the greened façade. The building is not connected to stormwater sewers, reflecting one of the main goals of this decentralized system of rainwater retention and harvesting. Stormwater events from heavy rainfall are managed with an overflow into a small constructed pond in one of the courtyards, from which the water can evaporate or drain into the ground. To protect the quality of groundwater, this drainage is only allowed through surface areas covered with vegetation. Some of the roof surfaces are also extensively greened to assist in retaining and treating stormwater.

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