Supplementary Material—Technology Shifts and Assumptions

The supplementary material contains information based on a number of sources that provide the statistical bases for the population and technology shifts that have occurred during the period 1945–2010. The appendix also includes the explicit assumptions used to provide the tables and figures presented both in the appendix and in the article.

Overall we base our estimates of nutrient loads from 1945–2010 on information about population development, installed WCs and treatment technologies, estimates of technology performance, and knowledge about the rules for different time periods prescribing certain technologies. The choice of time steps is made pragmatically on the availability of data. First, we calculated the shares of various technology groupings for the different time periods. Second, we calculated the overall nutrient capture capability of Swedish OSS, based on information and assumptions regarding nutrient capture of different technologies for the investigated time period. Results are presented here and graphically in Figure 3 in the article. Third, adding information about the nutrient content of grey water, black water, and excreta, and of the size of rural population, we could calculate the per capita and overall nutrient emission trend, shown in Figure 1 in the article.

The rural population development shown in Table S1 is a basis for several of the calculations. The increase in rural population from the 1970s and onwards should primarily be attributed to an increasing use of rural homes as summer homes. The following assumptions were made to fill-in gaps in the statistics. The household size of 1975 is linearly extrapolated using the data from 1960 and 1970. The household size of 1990 is assumed to be the same as for Sweden as a whole. The household size of 2010 is assumed to be the same as for Sweden as a whole.

Table S1. The development of the rural population in Sweden 1945–2010 [19,54–59].

	1945	**1960**	**1970**	**1975**	**1980**	**1990**	**2010**
Rural households *	647,341	545,921	503,329	452,729	528,211	624,423	690,736
Persons per rural household	4.1	3.1	2.8	2.7	2.7	2.1	2.1
Rural population	2,654,100	1,692,354	1,414,355	1,239,028	1,222,432	1,311,288	1,450,546

* Rural households comprise both permanent and vacation residents.

The starting point for calculating the shares of different technologies, shown in Table S3, is the record of installed WCs between 1945 and 1975 from the official population and housing censuses [19,54–56], shown in Table S2.

Table S2. Percentages of dry toilets and WCs 1945–1975 [19,54–56].

	1945	**1960**	**1970**	**1975**
Installed WCs	5%	40%	68%	82%
Installed latrines *	95%	60%	32%	18%

* Calculated. Share of WCs = 1—Share of latrines.

We assumed that the decreasing countryside population, shown in Table S1, implies the abandoning of old technologies, first latrines but later also other technologies. Further, after 1975 additional WCs connected to treatment technologies matching the existing rules of different times are installed. The increasing number of households is mostly corresponding to an increasing number of summer

homes, including permanent homes transformed to summer homes, and we assume that treatment technologies matching the rules of different time periods are applied when new OSS are installed. From 1980 onwards the calculations depart instead from the share of technologies as of recent estimates [5]. Looking backwards assumptions were made regarding when technologies appeared and how fast the technologies diffused. 1-/2-chambered sludge separators are assumed to be installed from 1945–1960 and are followed by 3-chambered separators w/o drainage pits that are applied until late 1960s. From about 1970 until today infiltration systems and constructed filter beds of higher capture capacities have been installed. In the 1970s came also the closed tanks, primarily used in summer homes. However, in many municipalities this technology have not been allowed since the mid-90s (e.g., Västervik, Tanum) and we assumed that this is the case for all municipalities in Sweden. We further assumed that urine separating systems appeared in the 1980s and that compact treatment plants is a quite recent phenomenon, mostly installed from the 1990s onwards.

Table S3. Calculates shares of different groups of technologies 1945–2010.

	1945 (%)	**1960 (%)**	**1970 (%)**	**1975 (%)**	**1980 (%)**	**1990 (%)**	**2010 (%)**
Latrines	95	64	34	18	13	10	5
1-/2-chambered sludge separator w/ or w/o drainage pit	5	36	39	44	29	16	6
3-chambered sludge separator w/ or w/o drainage pit			27	30	23	18	12
Closed tank				4	15	19	17
Sludge separator w/ soil infiltration or compact filters				4	19	35	55
Urine separating systems					1	2	3
Compact treatment plants						1	2

The following assumptions were made regarding the capture capabilities for different treatment technologies, summarized in Table S4 below. Latrines and urine sorting enable treatment through on-site nutrient cycling at individual lots or on agricultural land. We assumed this to be the major pathway for sorted urine and latrine and that the nutrient capture is very high, and that the major source of nutrient emissions is grey water (waste water from dishing, washing, bathing *etc*.). The actual nutrient capture is determined by several factors, including hydrogeology and agricultural practices. While the leakage estimates are valid for current conditions we use them also for historical conditions. The low figures for sludge separators and infiltration beds are confirmed by recent research showing that the nutrient capture is likely low, particularly with regard to phosphorus, and when conditions are poor the systems performance may decay quite rapidly [16,38]. Sludge separators were first installed with no subsequent treatment steps or were combined with drainage pits and have low nutrient capture capabilities [5]. Later soil infiltration and compact filters were developed from the

simpler drainage pits which implied higher nutrient capture capabilities. However, the function of early soil infiltration and compact filter systems is constrained by too little volumes and moreover their performance with time is decaying because of soil processes, particularly for phosphorus [16,38]. We used estimates for the average Swedish soil infiltration and compact filter systems also when looking backwards [5], assuming that this corresponds fairly well with systems with lower treatment potential in earlier stages, higher treatment potential systems in later stages, and decaying performance with time during the whole time period (1945–2010) when these kind of systems were applied. We assumed that closed tanks imply sewage collection and treatment at MWWTPs in all cases. In MWWTPs nutrient capture have improved as new treatment steps have been added from the 40s onwards. We assumed roughly that the performance has increased linearly MWWTPs from no treatment in the 60s to the degree of treatment in today's MWWTPs.

Table S4. Nutrient capture capabilities of various treatment technologies.

OSS technology	Assumed nutrient capture capability		Source	Nutrient capture according to source (%)
	N (%)	P (%)		
Latrine	90	90	Authors	
Urine separating systems	90	90	Authors	
1-/2-chambered sludge separator w/ or w/o drainage pit	10		[5]	10 ± 5
		15	[5]	15 ± 10
3-chambered sludge separator w/ or w/o drainage pit	10		[5]	10 ± 5
		15	[5]	15 ± 10
Closed tank	60		[7]	60
			[60]	56–64
		95	[60]	95
Sludge separator w/ soil infiltration or compact filters	27.5		[5]	Soil infiltration: 30 ± 10 Compact filter: 25 ± 10
		45	[5]	Soil infiltration: 50 ± 30 Compact filter: 40 ± 20
Compact treatment plants	45		[5]	40 ± 20
		80	[5]	80 ± 10

Following the calculations of nutrient capture capabilities we calculated the overall nutrient capture capability for different time periods by weighing the nutrient capture capability of different technology by the technologies' share, the result shown in Figure S1.

In the final step calculating the per capita load of nutrients we used reported data on the input to OSSs per capita [5]. We assumed that all households produce grey water containing 1 kg N and 0.12 kg P per person and year, and black water (water, urine, and feces) or excreta, either way containing 1.1 kg P and 9.7 kg N per person and year. Further, we assumed the per capita load of nutrients to OSSs to be the same between 1945–2010.

Figure S1. Calculated average nutrient capture capability of Swedish OSSs 1945–2010 and the "contribution" of different technologies to the overall capacity.