**Life Cycle Assessment of Pipes and Piping Process in Drinking Water Distribution Networks to Reduce Environmental Impact**

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**Table 1. Inventory data for production, transportation and installation of one meter of 100, 150, 200, 250, 400 and 500 mm ductile iron pipe ( HANYCO, 2016; TPWWC, 2017)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **LCA Phase** | **Input (process/ materials)** | **Ecoinvent Process/ Materials** | **Unit** | **Value 100 mm** | **Value 150 mm** | **Value 200 mm** | **Value 250 mm** | **Value 400 mm** | **Value 500 mm** |
| Production | Cast iron | Cast iron {GLO}| market for | Alloc Def, S | kg | 15.83 | 24.00 | 32.3 | 42.50 | 80.33 | 111.50 |
| Production Process | Metal working, average for metal product manufacturing {GLO}| market for | Alloc Def, S | kg | 15.83 | 24.00 | 32.3 | 42.50 | 80.33 | 111.50 |
| Cement mortar (interior coating) | Cement mortar {GLO}| market for | Alloc Def, S | kg | 1.74 | 2.00 | 3.53 | 5.06 | 13.63 | 17.50 |
| Bitumen (external coating) | Bitumen adhesive compound, hot {GLO}| market for | Alloc Def, S | kg | 0.09 | 0.14 | 0.19 | 0.24 | 0.38 | 0.47 |
| Zinc oxide (external coating) | Zinc {GLO}| market for | Alloc Def, S | kg | 0.04 | 0.06 | 0.08 | 0.10 | 0.16 | 0.20 |
| Zinc coating process | Zinc coat, pieces, adjustment per micro-m {GLO}| market for | Alloc Def, S | m2 | 0.31 | 0.47 | 0.63 | 0.79 | 1.26 | 1.57 |
| Transportation | Transportation of pipes | Transport, freight, lorry >32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 0.53 | 0.79 | 1.08 | 1.44 | 2.84 | 3.89 |
| Transportation of sand | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 5.19 | 6.21 | 7.23 | 8.33 | 11.73 | 14.14 |
| Transportation of gravel | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 3.62 | 4.46 | 5.32 | 6.21 | 9.04 | 11.06 |
| Transportation of extra soil of the trench excavation | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 4.51 | 5.46 | 6.44 | 7.45 | 10.65 | 12.93 |
| Installation | Crushed gravel | Gravel, crushed {GLO}| market for | Alloc Def, S | kg | 120.83 | 148.61 | 177.31 | 206.92 | 301.24 | 368.69 |
| Sand | Sand {GLO}| market for | Alloc Def, S | kg | 172.94 | 206.85 | 241.74 | 277.59 | 390.96 | 471.38 |
| Excavator | Excavation, hydraulic digger {GLO}| market for | Alloc Def, S | m3 | 0.68 | 0.77 | 0.87 | 0.98 | 1.32 | 1.58 |
| Vibrating compactor | Machine operation, diesel, < 18.64 kW, steady-state {GLO}| market for | Alloc Def, S | min. | 20 | 20 | 30.00 | 30.00 | 40 | 50 |

**Table 2. Inventory data for production, transportation and installation of one meter of 200, 500 and 600 mm steel pipe (TPWWC, 2017)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **LCA Phase** | **Input (process/ materials)** | **Ecoinvent Process/ Materials** | **Unit** | **Value 200 mm** | **Value 500 mm** | **Value 600 mm** |
| Production | Steel | Steel, low-alloyed, hot rolled {GLO}| market for | Alloc Def, S | kg | 25.55 | 98.64 | 118.68 |
| Production Process | Metal working, average for steel product manufacturing {GLO}| market for | Alloc Def, S | kg | 25.55 | 98.64 | 118.68 |
| Cement mortar (interior coating) | Cement mortar {GLO}| market for | Alloc Def, S | kg | 3.08 | 17.50 | 19.12 |
| Bitumen (external coating) | Bitumen adhesive compound, hot {GLO}| market for | Alloc Def, S | kg | 0.09 | 0.47 | 0.56 |
| Enameling process | Enameling {GLO}| market for | Alloc Def, S | m2 | 0.63 | 1.57 | 1.88 |
| Transportation | Transportation of pipes | Transport, freight, lorry >32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 0.86 | 3.50 | 4.15 |
| Transportation of sand | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 7.25 | 14.14 | 16.67 |
| Transportation of gravel | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 5.32 | 11.06 | 13.19 |
| Transportation of extra soil of the trench excavation | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 6.44 | 12.93 | 15.32 |
| Installation | Crushed gravel | Gravel, crushed {GLO}| market for | Alloc Def, S | kg | 177.31 | 368.69 | 439.79 |
| Sand | Sand {GLO}| market for | Alloc Def, S | kg | 241.74 | 471.38 | 555.66 |
| Excavator | Excavation, hydraulic digger {GLO}| market for | Alloc Def, S | m3 | 0.87 | 1.58 | 1.85 |
| Vibrating compactor | Machine operation, diesel, < 18.64 kW, steady-state {GLO}| market for | Alloc Def, S | min. | 30 | 50.00 | 60.00 |

**Table 3. Inventory data for production, transportation and installation of one meter of 63, 200 and 500 mm PVC pipe (TPWWC, 2017)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **LCA Phase** | **Input (process/ materials)** | **Ecoinvent Process/ Materials** | **Unit** | **Value 63 mm** | **Value 200 mm** | **Value 500 mm** |
| Production | Polyvinylchloride | Polyvinylchloride, bulk polymerised {GLO}| market for | Alloc Def, S | kg | 0.85 | 8.08 | 49.97 |
| Limestone | Limestone, crushed, washed {GLO}| market for | Alloc Def, S | kg | 0.09 | 0.43 | 2.63 |
| Production Process | Extrusion, plastic pipes {GLO}| market for | Alloc Def, S | kg | 0.94 | 8.51 | 52.60 |
| Bitumen (external coating) | Bitumen adhesive compound, hot {GLO}| market for | Alloc Def, S | kg | 0.01 | 0.02 | 0.04 |
| Transportation | Transportation of pipes | Transport, freight, lorry >32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 0.03 | 0.26 | 1.58 |
| Transportation of sand | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 8.43 | 11.80 | 23.96 |
| Transportation of gravel | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 2.04 | 2.55 | 4.08 |
| Transportation of extra soil of the trench excavation | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 5.40 | 8.10 | 19.44 |
| Installation | Crushed gravel | Gravel, crushed {GLO}| market for | Alloc Def, S | kg | 68.00 | 85.00 | 136.00 |
| Sand | Sand {GLO}| market for | Alloc Def, S | kg | 281.08 | 393.48 | 798.75 |
| Excavator | Excavation, hydraulic digger {GLO}| market for | Alloc Def, S | m3 | 0.60 | 0.80 | 1.52 |
| Vibrating compactor | Machine operation, diesel, < 18.64 kW, steady-state {GLO}| market for | Alloc Def, S | min. | 20.00 | 30.00 | 50.00 |

**Table 4. Inventory data for production, transportation and installation of one meter of 90, 200 and 500 mm HDPE pipe (TPWWC, 2017)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **LCA Phase** | **Input (process/ materials)** | **Ecoinvent Process/ Materials** | **Unit** | **Value 90 mm** | **Value 200 mm** | **Value 500 mm** |
| Production | Polyethylene | Polyethylene, high density, granulate {GLO}| market for | Alloc Def, S | kg | 2.12 | 10.40 | 64.50 |
| Production Process | Extrusion, plastic pipes {GLO}| market for | Alloc Def, S | kg | 2.12 | 10.40 | 64.50 |
| Transportation | Transportation of pipes | Transport, freight, lorry >32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 0.06 | 0.31 | 1.94 |
| Transportation of sand | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 8.43 | 11.80 | 23.96 |
| Transportation of gravel | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 2.04 | 2.55 | 4.08 |
| Transportation of extra soil of the trench excavation | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 5.40 | 8.10 | 19.44 |
| Installation | Crushed gravel | Gravel, crushed {GLO}| market for | Alloc Def, S | kg | 68.00 | 85.00 | 136.00 |
| Sand | Sand {GLO}| market for | Alloc Def, S | kg | 276.55 | 393.48 | 798.75 |
| Excavator | Excavation, hydraulic digger {GLO}| market for | Alloc Def, S | m3 | 0.60 | 0.80 | 1.52 |
| Vibrating compactor | Machine operation, diesel, < 18.64 kW, steady-state {GLO}| market for | Alloc Def, S | min. | 20.00 | 30.00 | 50.00 |

**Table 5. Inventory data for production, transportation and installation of one meter of 100, 200 and 525 mm fibrocement type I pipe (TPWWC, 2017)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **LCA Phase** | **Input (process/ materials)** | **Ecoinvent Process/ Materials** | **Unit** | **Value 100 mm** | **Value 200 mm** | **Value 525 mm** |
| Production | Fibrocement | Fibre cement, pipe {GLO}| market for | Alloc Def, S | kg | 9.50 | 29.60 | 144.00 |
| Cement mortar (interior coating) | Cement mortar {GLO}| market for | Alloc Def, S | kg | 1.50 | 3.00 | 7.70 |
| Transportation | Transportation of pipes | Transport, freight, lorry >32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 0.33 | 0.98 | 4.55 |
| Transportation of sand | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 9.81 | 13.31 | 24.86 |
| Transportation of Concrete | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 2.54 | 3.45 | 6.44 |
| Transportation of extra soil of the trench excavation | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 6.54 | 8.87 | 16.57 |
| Installation | Concrete | Concrete, 20MPa {GLO}| market for | Alloc Def, S | cm3 | 60537.50 | 82150.00 | 153437.50 |
| Sand | Sand {GLO}| market for | Alloc Def, S | kg | 326.90 | 443.61 | 828.56 |
| Excavator | Excavation, hydraulic digger {GLO}| market for | Alloc Def, S | m3 | 0.75 | 0.96 | 1.71 |
| Vibrating compactor | Machine operation, diesel, < 18.64 kW, steady-state {GLO}| market for | Alloc Def, S | min. | 20.00 | 30.00 | 50.00 |

**Table 6. Inventory data for production, transportation and installation of one meter of 100, 200 and 525 mm fibrocement type II pipe (TPWWC, 2017)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **LCA Phase** | **Input (process/ materials)** | **Ecoinvent Process/ Materials** | **Unit** | **Value 100 mm** | **Value 200 mm** | **Value 525 mm** |
| Production | Fibrocement | Fibre cement, pipe {GLO}| market for | Alloc Def, S | kg | 9.50 | 29.60 | 144.00 |
| Cement mortar (interior coating) | Cement mortar {GLO}| market for | Alloc Def, S | kg | 1.50 | 3.00 | 7.70 |
| Transportation | Transportation of pipes | Transport, freight, lorry >32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 0.33 | 0.98 | 4.55 |
| Transportation of sand | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 9.24 | 12.11 | 21.43 |
| Transportation of gravel | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 3.62 | 5.32 | 11.06 |
| Transportation of extra soil of the trench excavation | Transport, freight, lorry 16-32 metric ton, EURO4 {GLO}| market for | Alloc Def, S | tkm | 6.54 | 8.87 | 16.57 |
| Installation | Crushed gravel  | Gravel, crushed {GLO}| market for | Alloc Def, S | kg | 120.83 | 177.31 | 368.69 |
| Sand | Sand {GLO}| market for | Alloc Def, S | kg | 307.94 | 403.74 | 714.38 |
| Excavator | Excavation, hydraulic digger {GLO}| market for | Alloc Def, S | m3 | 0.75 | 0.96 | 1.71 |
| Vibrating compactor | Machine operation, diesel, < 18.64 kW, steady-state {GLO}| market for | Alloc Def, S | min. | 30.00 | 40.00 | 60.00 |

**References**

Hamoun Nyzeh Co (HANYCO ). (2016). Manufacturer of Ductile Iron Pipes. Retrieved from http://hanyco.ir/ (accessed September 2016).

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