pymrio-tutorial-for-wiod

October 23, 2018

1 Quick Start Pymrio Tutorial using WIOD

This notebook contains the interactive version of the quick start given in the Pymrio article (Stadler et al 2018 sub).

Pymrio requires a Python version >= 3.5. If you don't have Python installed, I recommend to use the Anaconda Scientific Python package.

Pymrio is available on the Python Package Index PyPI and on the Anaconda Cloud. Thus, two possibilities exist to install Pymrio and all required packages.

For using the version on PyPI use:

```
pip install pymrio --upgrade
```

To install from the Anaconda Cloud do:

```
conda install -c konstantinstadler pymrio
```

You can than import the Pymrio package with

```
In [1]: import pymrio
```

In this example here, we will use the WIOD MRIO database.

First, the Pymrio MRIO download function is used to get the WIOD MRIO database with:

```
In [2]: raw_wiod_path = '/tmp/wiod/raw'
        pymrio.download_wiod2013(storage_folder=raw_wiod_path,
                                 years=[2008])
```

```
Out[2]: Description: WIOD metadata file for pymrio
        MRIO Name: WIOD
        System: ixi
        Version: data13
        File: /tmp/wiod/raw/metadata.json
        History:
        20181023 11:50:53 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/water/wa
        20181023 11:50:52 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/material
        20181023 11:50:52 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/land/lan
        20181023 11:50:52 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/AIR/AIR_
        20181023 11:50:51 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/CO2/CO2_
```

```
20181023 11:50:50 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/EM/EM_ma
20181023 11:50:49 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/EU/EU_ma
20181023 11:50:48 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/SEA/WIOD
20181023 11:50:48 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/update_s
```

This downloads the 2008 MRIO table from WIOD. Omitting the year parameter would result getting all years. The function returns a Pymrio meta data object, which gives information about the WIOD version, system (in this case industry by industry) and records about from where the data was received.

To parse the database into a Pymrio object use:

```
In [3]: wiod = pymrio.parse_wiod(raw_wiod_path, year=2008)
```

The available data can be explored by for example:

```
In [4]: wiod.get_sectors()

Out[4]: Index(['AtB', 'C', '15t16', '17t18', '19', '20', '21t22', '23', '24', '25',
               '26', '27t28', '29', '30t33', '34t35', '36t37', 'E', 'F', '50', '51',
               '52', 'H', '60', '61', '62', '63', '64', 'J', '70', '71t74', 'L', 'M',
               'N', 'O', 'P'],
              dtype='object', name='sector')
```

or

```
In [5]: wiod.get_regions()

Out[5]: Index(['AUS', 'AUT', 'BEL', 'BGR', 'BRA', 'CAN', 'CHN', 'CYP', 'CZE', 'DEU',
               'DNK', 'ESP', 'EST', 'FIN', 'FRA', 'GBR', 'GRC', 'HUN', 'IDN', 'IND',
               'IRL', 'ITA', 'JPN', 'KOR', 'LTU', 'LUX', 'LVA', 'MEX', 'MLT', 'NLD',
               'POL', 'PRT', 'ROU', 'RUS', 'SVK', 'SVN', 'SWE', 'TUR', 'TWN', 'USA',
               'RoW'],
              dtype='object', name='region')

In [6]: wiod.Z

Out[6]: region                AUS                                                  \
        sector                AtB           C        15t16       17t18          19
        region sector
        AUS    AtB     4445.324330   41.919400  15625.681890  536.968630  154.395870
               C         16.277934 3838.070873    189.934275   11.313686    3.253063
               15t16   1049.495726  100.611347   6754.110522   68.387761   19.663697
               17t18     36.908420   43.779214    108.986668  355.675875  102.268333
               19         9.518107   11.289978     28.105965   91.723266   26.373410
               20        36.819811   47.491171     33.027878    7.296923    2.098101
               21t22    115.900527  153.248506   1246.425549   52.200097   15.009220
               23       490.156419 1026.213186    158.889100    9.179523    2.639409
               24      1025.411077  395.338597    254.521411   58.428801   16.800175
               25        79.516332  189.301500    747.545652   34.083913    9.800233
```

	26	38.658080	105.010424	262.224086	5.283083	1.519054
	27t28	212.089806	1310.988269	836.157336	42.125453	12.112433
	29	168.914698	614.130627	121.573026	9.601957	2.760879
	30t33	100.297729	364.656884	72.187314	5.701425	1.639347
	34t35	94.161797	279.637968	68.165787	8.294429	2.384917
	36t37	52.529450	213.596124	135.683995	26.057759	7.492447
	E	698.423156	1719.046355	885.618629	86.361355	24.831684
	F	633.714316	4242.094785	376.754403	28.695921	8.251007
	50	1132.348543	2138.419658	1023.262884	159.073383	45.738761
	51	1394.463193	1572.454263	4088.518869	419.871502	120.726663
	52	1445.528277	1659.816747	3579.884070	371.567853	106.837791
	H	140.934734	216.771700	561.956674	27.457908	7.895041
	60	476.976916	3184.818553	1993.405269	126.355111	36.331187
	61	9.552743	170.427724	31.177072	4.611883	1.326064
	62	6.869618	20.121560	11.067713	1.786162	0.513581
	63	297.699414	738.735542	1195.706686	45.976713	13.219798
	64	223.155110	423.626089	355.814018	35.236625	10.131668
	J	1299.842059	4293.057285	967.646850	59.138767	17.004318
	70	551.797175	1786.808419	797.474903	32.553813	9.360274
	71t74	1180.063104	5310.446524	3035.907428	368.573815	105.976926
...		...	...	...	...	...
RoW	20	1.635056	2.013566	0.820348	0.216980	0.062394
	21t22	7.724918	13.129569	217.877677	2.003884	0.576182
	23	388.152158	836.374409	81.538931	2.390291	0.687287
	24	365.270981	132.696731	32.705396	14.943534	4.296752
	25	8.286214	22.575945	90.951788	2.964467	0.852379
	26	1.956064	6.043732	11.152563	0.099052	0.028483
	27t28	9.581514	191.520139	34.196454	2.872105	0.825822
	29	35.895862	148.406916	4.062407	0.206493	0.059371
	30t33	5.438695	14.663099	4.288701	0.942037	0.270862
	34t35	3.580771	6.292762	1.143145	0.089681	0.025786
	36t37	1.423158	15.919915	2.520675	0.997691	0.286871
	E	0.802647	18.560578	1.105187	0.052474	0.015090
	F	0.690587	4.550382	0.398577	0.018475	0.005314
	50	0.055638	0.158419	0.091477	0.004071	0.001171
	51	2.752223	189.554149	11.612952	0.481597	0.138475
	52	1.031890	1.526614	3.043862	0.176287	0.050688
	H	0.783462	1.108244	3.597303	0.117633	0.033825
	60	0.680310	190.942239	7.225673	0.281982	0.081079
	61	0.085508	0.190833	0.040526	0.003698	0.001063
	62	7.703932	22.053451	12.157162	2.137970	0.614733
	63	0.308886	0.802305	0.698779	0.064745	0.018614
	64	0.166596	0.499486	0.348924	0.032884	0.009460
	J	4.774312	8.175419	8.364439	0.128402	0.036924
	70	7.339967	23.635663	8.385978	0.273455	0.078627
	71t74	3.657849	17.761648	9.827292	1.145630	0.329414
	L	0.547432	0.780406	1.176073	0.200903	0.057766
	M	1.319036	9.927575	11.742183	2.639874	0.759049

	N	7.894845	0.291041	11.603507	2.279403	0.655404
	O	1.244926	3.686620	4.381357	0.155217	0.044633
	P	0.001018	0.000104	0.003666	0.000135	0.000039

region						\
sector		20	21t22	23	24	25
region	sector					
AUS	AtB	936.835140	273.018600	0.000000	215.708440	93.909230
	C	14.271582	58.136067	4424.333299	193.328895	20.968263
	15t16	14.570366	49.431980	36.266290	835.587643	54.070009
	17t18	18.335691	50.188234	15.538649	45.917943	45.612614
	19	4.728489	12.942764	4.007176	11.841522	11.762783
	20	931.529917	29.447854	10.273590	19.271625	19.486462
	21t22	90.326674	2821.000424	23.198240	363.916574	142.223056
	23	35.551012	77.346703	518.540713	250.877221	41.087803
	24	134.600162	414.014715	254.533734	1940.073909	858.289530
	25	36.346518	308.640250	35.017383	356.994995	269.405154
	26	40.469744	29.765072	8.536396	105.011698	39.029102
	27t28	307.140650	183.821644	39.748282	376.009535	192.166872
	29	22.279107	45.205836	36.726841	49.857619	28.242531
	30t33	13.228830	26.842204	21.807568	29.604327	16.769776
	34t35	8.080558	19.639293	18.150425	25.406816	11.405865
	36t37	110.342068	35.268883	21.252913	64.355459	29.135448
	E	143.282141	356.331393	124.990480	359.975571	187.401518
	F	109.473492	151.285346	935.469320	167.746506	93.523215
	50	230.146065	723.933947	115.779055	392.670136	231.061142
	51	276.108617	963.440976	976.941746	1308.409695	535.714326
	52	289.884901	858.592422	1003.348917	1302.437162	535.855098
	H	23.433113	167.690188	103.972792	168.583295	31.931233
	60	218.706857	510.934567	264.079532	529.984384	320.186820
	61	3.898249	15.919886	15.316702	13.456574	5.596796
	62	1.669552	11.293316	2.145138	6.468971	1.904794
	63	325.523642	634.162539	98.547353	630.174898	72.132960
	64	74.415816	321.615785	114.934853	143.609205	71.615890
	J	111.468536	441.552736	97.016295	296.043420	121.990028
	70	300.402024	541.707671	186.950544	98.494018	50.868687
	71t74	557.009305	2787.056493	1262.566488	2654.652613	1383.027258
...		...	...	...	...	...
RoW	20	59.254639	1.921591	0.293189	0.419081	0.896964
	21t22	10.939833	305.243836	2.718898	43.005354	12.827419
	23	25.409174	52.937556	426.332774	189.227887	25.663685
	24	45.776375	137.849053	88.781323	694.935609	304.297810
	25	4.080999	38.578026	4.433015	43.078751	33.263153
	26	1.540591	0.842093	0.991921	5.264341	1.845787
	27t28	19.202156	17.107983	2.899187	23.417741	40.398734
	29	4.226874	5.044632	4.710717	6.153871	1.448788
	30t33	0.581584	5.573272	0.601050	3.175119	2.472000
	34t35	0.295067	0.589052	0.144417	0.873163	0.518826

	36t37	1.144750	1.872070	0.537275	2.212297	1.106440
	E	0.173761	0.567528	20.428639	0.819155	0.253561
	F	0.228649	0.150437	0.984623	0.227128	0.110467
	50	0.012600	0.039960	0.049854	0.052195	0.025508
	51	0.853480	4.639344	230.537056	6.007003	1.436657
	52	0.267343	1.589181	0.516815	1.104595	0.320696
	H	0.112285	0.844576	0.471689	0.894151	0.123268
	60	0.435869	2.825101	234.376543	3.367219	0.414917
	61	0.008164	0.032342	0.082525	0.046836	0.007787
	62	1.580617	13.245788	2.369183	7.540798	2.183210
	63	0.151014	0.529874	0.096219	0.398736	0.083757
	64	0.065116	0.304461	0.102210	0.231570	0.101406
	J	0.501054	3.041203	0.527920	1.128715	0.542113
	70	3.690224	5.954991	2.422823	0.176277	0.184588
	71t74	1.860358	9.415961	4.389323	8.278023	4.489652
	L	0.248589	0.636937	0.238198	1.078893	0.160527
	M	1.003295	4.474255	4.120725	4.517280	1.687657
	N	1.749095	6.793279	0.164896	18.550374	0.174962
	O	0.562692	2.533730	0.758305	2.141030	0.484539
	P	0.000031	0.000096	0.000021	0.000116	0.000052

region		...	RoW			\
sector		...	63	64	J	
region	sector	...				
AUS	AtB	...	19.761917	0.001627	0.140044	
	C	...	0.211888	0.034300	0.005817	
	15t16	...	1.621756	1.588110	3.701685	
	17t18	...	0.401032	0.181367	1.492579	
	19	...	0.039708	0.017958	0.147786	
	20	...	0.027123	0.082776	0.063378	
	21t22	...	2.204172	10.102687	15.418063	
	23	...	59.028995	4.487274	11.189084	
	24	...	2.603711	1.444149	1.194342	
	25	...	0.973279	2.427753	0.704863	
	26	...	0.186875	0.421755	0.195426	
	27t28	...	15.617744	7.959440	2.380652	
	29	...	3.642359	30.309729	6.825963	
	30t33	...	2.002236	16.661519	3.752291	
	34t35	...	12.703247	8.769379	12.768384	
	36t37	...	0.226041	1.816351	1.501001	
	E	...	0.158169	0.222314	0.298537	
	F	...	0.967638	3.020002	6.822620	
	50	...	0.542576	1.055301	1.163450	
	51	...	0.822974	0.880188	2.617088	
	52	...	3.508417	8.412820	2.943161	
	H	...	13.417060	5.803010	31.833836	
	60	...	24.160506	27.963040	34.284311	
	61	...	2.683645	27.565014	25.181994	

```
        62          ...        56.890998    228.034250    187.103415
        63          ...        23.523008     76.260841     59.942885
        64          ...         0.183698      3.195211      4.168414
        J           ...        10.691209     38.702169     87.947969
        70          ...         1.371040     55.154968     51.222023
        71t74       ...        13.609769     44.055788    110.840096
...                 ...              ...           ...           ...
RoW     20          ...        80.089178     38.342266     12.072937
        21t22       ...      2356.505474   5432.580816   7910.918929
        23          ...       940.236675    261.091828    154.913923
        24          ...       259.001665     86.217475     90.520415
        25          ...      1122.804886    762.399457    140.149436
        26          ...       119.947154     60.337788     18.657645
        27t28       ...      1298.244145    315.873918    171.199863
        29          ...       697.828174    319.985813    314.995799
        30t33       ...       818.546621   8308.403067    731.275786
        34t35       ...      1252.400960   1279.511149    517.703475
        36t37       ...       103.922288    113.850921    471.973179
        E           ...      4605.709269   7342.310696   5072.978446
        F           ...       982.318867   2242.910054   3428.713588
        50          ...       522.931361    593.953802    533.712735
        51          ...      3519.981195   7342.086914   2956.802019
        52          ...      2200.648191   3472.751467   2002.609268
        H           ...      5697.775736   2180.164612   7534.073416
        60          ...      7703.649094   5140.042568   7039.531612
        61          ...       319.845929    351.739712    393.717271
        62          ...       532.908584   1341.365292   1312.401998
        63          ...      3504.280492   1807.314685   1701.271137
        64          ...      2172.194846  20440.020040  11710.122737
        J           ...      7415.709712   8091.081325  38655.926218
        70          ...      1727.970393   5199.410339   7493.075988
        71t74       ...      6246.240339  12482.298686  24886.499828
        L           ...       608.700335    709.004146   1595.531658
        M           ...        91.678620    463.402398   1802.804212
        N           ...        39.843405    106.735687    305.274672
        O           ...      5414.944076   4371.240663   5815.525102
        P           ...         1.324062      0.244611      1.104726

region                                                               \
sector                    70         71t74             L             M
region sector
AUS    AtB         0.043667     11.680006      3.113827     61.711687
       C           0.088101     14.418832      0.315809      0.182157
       15t16       2.743954     27.665274     14.865583     86.096798
       17t18       0.632427      1.492750      6.550554      0.878764
       19          0.062619      0.147803      0.648594      0.087010
       20          0.205954      0.790532      2.353193      2.554166
       21t22       6.195107     48.596887     56.890466     21.913868
```

	23	11.512628	36.303514	27.566443	17.222495
	24	9.237368	19.609616	28.268265	42.763999
	25	3.349751	6.259412	2.576908	3.199048
	26	0.657503	1.604297	1.160610	1.514350
	27t28	18.293034	25.094179	4.177664	5.533838
	29	28.606393	41.232405	7.775303	17.255305
	30t33	15.725181	22.665809	4.274151	9.485390
	34t35	12.610675	64.711016	21.845125	12.221815
	36t37	0.734132	5.457432	3.653690	3.040151
	E	1.804297	0.696923	0.819074	0.433625
	F	4.445031	6.978164	3.820432	4.213175
	50	0.619550	0.820108	3.190926	0.401245
	51	1.334045	8.044024	8.112138	13.165919
	52	4.183650	25.137596	9.350485	9.915846
	H	6.093826	44.016163	31.470631	22.222129
	60	29.296585	51.018691	66.987976	39.638572
	61	128.915922	66.003832	27.081238	6.700347
	62	40.923609	416.402802	518.481234	387.002863
	63	23.682097	132.257649	162.850890	120.792474
	64	0.398777	1.136361	4.488764	2.069959
	J	49.862781	73.172178	17.970300	40.594369
	70	81.507135	1.324506	14.642011	7.911327
	71t74	45.926864	97.594121	30.529568	59.538339
...		...	...	...	...
RoW	20	26.345271	629.084892	1884.054328	2120.766430
	21t22	1128.083167	26948.165198	16081.684247	9758.327387
	23	129.072765	789.857491	574.234856	141.229352
	24	172.206457	1469.037784	568.857200	464.549470
	25	493.458933	3238.293742	384.585818	748.594202
	26	135.596128	389.433240	439.866913	502.917719
	27t28	733.140609	4511.622232	548.761711	543.615393
	29	181.223515	1068.322357	753.097670	271.294575
	30t33	808.302796	21372.986647	1858.083732	2393.918095
	34t35	418.842054	6459.762846	2627.353449	1120.680148
	36t37	181.271520	482.787859	773.675064	852.380832
	E	5141.941351	12517.586986	15224.240044	12110.158949
	F	7483.145885	5407.731676	10000.889751	6437.551020
	50	225.393607	984.574183	1437.815851	342.158934
	51	2056.102533	13468.319458	8755.578709	4942.954370
	52	1022.444732	6822.892202	4692.901833	2286.924606
	H	1565.207855	12160.455853	16699.714473	7750.382855
	60	1167.017249	10630.975028	10255.302827	4952.250191
	61	249.455177	1314.984794	916.026979	435.280134
	62	197.515757	2930.795161	3507.522443	2074.276308
	63	373.643784	3223.972374	4095.498850	1417.898957
	64	1468.996337	9246.282287	15881.469928	6012.447058
	J	5758.940639	19989.913847	23896.327061	9546.835763
	70	2705.769797	9495.163791	8103.153981	5036.228134

	71t74	6015.478162	70478.453504	20430.836359	13305.638974
	L	620.253937	1194.982705	4557.146576	518.488155
	M	212.193133	1571.999239	7706.676330	5223.189539
	N	70.364956	895.599603	1415.975389	840.530518
	O	2897.014578	14958.970521	15443.391745	7897.357003
	P	1.141934	50.552086	0.000000	1.089908

region				
sector		N	O	P
region	sector			
AUS	AtB	9.898359	10.256983	0.000038
	C	0.273387	0.493510	0.000861
	15t16	46.736852	79.637133	0.006089
	17t18	2.252624	2.428735	0.001057
	19	0.223040	0.240478	0.000105
	20	1.827102	1.287573	0.010418
	21t22	17.326665	25.336693	0.025942
	23	18.549700	17.863948	0.011255
	24	112.870262	29.349604	0.052557
	25	4.867827	37.445945	0.008494
	26	1.381380	2.173674	0.001937
	27t28	4.012130	26.919745	0.049209
	29	6.985789	19.145209	0.031949
	30t33	3.840148	10.524287	0.017563
	34t35	5.288575	124.684698	0.005111
	36t37	2.261301	6.176947	0.330733
	E	0.588291	0.542892	0.000114
	F	4.269064	3.135682	0.006102
	50	0.715443	0.335334	0.000000
	51	10.882036	17.335205	0.125509
	52	14.368875	9.505814	0.045543
	H	15.193905	8.820562	0.024843
	60	6.561055	44.037984	0.014616
	61	2.041265	17.273710	0.000000
	62	28.960407	154.036071	0.000035
	63	9.267663	53.423142	0.000042
	64	1.476196	0.879504	0.000243
	J	12.824709	34.707057	0.069814
	70	0.554078	15.369971	0.000000
	71t74	18.124551	33.468160	0.097561
...		...	...	...
RoW	20	1932.161785	914.755872	0.019687
	21t22	6011.875100	10934.428273	2.548514
	23	242.320646	423.896780	0.056465
	24	10243.419875	1465.864732	0.523719
	25	2193.842232	2876.932893	0.139278
	26	1116.624356	400.017883	0.111932
	27t28	931.955552	1147.905601	0.648180

```
29       3154.318917    314.337084   0.227289
30t33    2193.940291   4724.352592   1.743540
34t35     392.761307   7211.302026   0.984097
36t37     323.697939    504.572681   0.169314
E       12791.419341  10535.612431   4.831273
F       11354.319342   3839.537017  22.570339
50       1088.152585    555.415078   0.513696
51      19728.444632   9261.002711   4.393748
52       8058.010782   4256.950765   6.790453
H        5346.893566   4441.279950   1.070657
60       6210.736712   5982.700080  13.287645
61        803.452478    647.422802   0.257212
62        875.609110   1119.259998   0.346236
63       2264.941271   2108.901331   0.387366
64       7642.069297   4260.482612   8.457208
J        3563.218290   8195.767795  54.664765
70       6230.303094   7501.857446   0.007471
71t74   15560.647836  12040.071161  83.100716
L         921.621306    901.624286   0.000000
M        1488.980938    527.910083   0.001030
N        3513.234966    395.244668   0.000020
O        8895.570576  16565.733127  44.703532
P           4.570108     41.517464   3.460032

[1435 rows x 1435 columns]
```

WIOD includes several satellite accounts, which are stored as child objects in Pymrio. For example, in order to see the AIR emissions provided by WIOD:

```
In [7]: wiod.AIR.F
```

```
Out[7]: region             AUS                                          \
        sector             AtB             C          15t16         17t18
        stressor
        CO2       6.471152e+03  2.331841e+04    3256.861259    392.819896
        CH4       3.226169e+06  1.370016e+06    1221.450093     41.723574
        N2O       6.527106e+04  1.243851e+02     527.652440     10.773378
        NOX       2.000881e+05  1.709849e+05   70375.533177   3875.234721
        SOX       1.976645e+04  4.713841e+04   45815.675397   1068.354291
        CO        1.496859e+06  7.159254e+05  227663.413138  16225.875707
        NMVOC     3.824729e+05  2.409498e+05  141642.740887   5460.933412
        NH3       4.049434e+05  4.575323e+02     112.157985      4.313657

        region                                                          \
        sector             19            20         21t22            23
        stressor
        CO2         91.570641    147.075293   2100.167306    7928.850694
        CH4          6.112471     64.722688    189.787544   33785.867211
```

```
N2O          1.335362     14.793543    111.798406     146.523698
NOX        964.709338   9146.373832  36269.747108   18894.321469
SOX        265.958435   2521.542160  26680.445075  150018.069958
CO        4039.304699  38296.499606  82187.571692   56833.653485
NMVOC     1359.456610  12888.958231  28691.901753   65893.299291
NH3          0.449874     13.342974     48.333137       4.143371

region                                ...            RoW                \
sector               24           25 ...             63              64
stressor                              ...
CO2          8832.607331    82.623337 ...   4.530961e+04   23843.716275
CH4           768.018325    22.631731 ...   2.031444e+04    2430.969769
N2O         10421.185919     6.723839 ...   7.185897e+02     320.774141
NOX         34546.808023   663.707765 ...   1.419601e+05   87411.639720
SOX         91733.983039   182.976023 ...   6.973313e+04   42938.026115
CO         393632.686253  2778.990301 ...   1.385415e+06  853066.323392
NMVOC      105133.073315   935.288872 ...   3.377663e+05  207978.880902
NH3          366.328954     4.740067 ...   4.569925e+02     324.340516

region                                                                  \
sector                J             70         71t74             L
stressor
CO2         17594.617416   11774.769870  5.787274e+04  1.118612e+05
CH4          3979.962245    5525.320218  1.617241e+04  8.865122e+04
N2O           342.725185     215.478088  1.228492e+03  2.995831e+03
NOX         68809.569199   60385.601411  2.027940e+05  4.224802e+05
SOX         33800.385037   29662.394375  9.961571e+04  2.075292e+05
CO         671525.284261  589314.228014  1.979104e+06  4.123062e+06
NMVOC      163718.896513  143675.714632  4.825085e+05  1.005209e+06
NH3          229.110878     244.663450  1.643215e+03  1.357458e+03

region
sector                M             N             O    P
stressor
CO2         25382.470248  4.575128e+04  4.851286e+04  0.0
CH4          5001.012041  1.394311e+04  1.360473e+07  0.0
N2O           272.108324  7.680525e+03  9.170715e+04  0.0
NOX         99579.016981  1.666314e+05  1.565510e+05  0.0
SOX         48914.840693  8.185206e+04  7.690040e+04  0.0
CO         971810.003503  1.626186e+06  1.527810e+06  0.0
NMVOC      236928.772636  3.964667e+05  3.724824e+05  0.0
NH3          113.829614  6.203676e+02  4.965187e+03  0.0

[8 rows x 1435 columns]
```

WIOD, however, does neither provide any normalized data (A-matrix, satellite account coefficient data) nor any consumption based accounts (footprints).

In order to calculate them, one could go through all the missing data and compute each ac-

count. Pymrio provides the required function, for example to calculate the A-matrix:

```
In [8]: x = pymrio.calc_x(Z=wiod.Z, Y=wiod.Y)
        A = pymrio.calc_A(Z=wiod.Z, x=x)

In [9]: A.head()
```

Out[9]:

region		AUS						\
sector		AtB	C	15t16	17t18	19	20	
region	sector							
AUS	AtB	0.095452	0.000346	0.220811	0.086780	0.096757	0.093637	
	C	0.000350	0.031718	0.002684	0.001828	0.002039	0.001426	
	15t16	0.022535	0.000831	0.095444	0.011052	0.012323	0.001456	
	17t18	0.000793	0.000362	0.001540	0.057481	0.064090	0.001833	
	19	0.000204	0.000093	0.000397	0.014824	0.016528	0.000473	

region						...	\
sector		21t22	23	24	25	...	
region	sector					...	
AUS	AtB	0.009559	0.000000	0.008643	0.008967	...	
	C	0.002035	0.220910	0.007746	0.002002	...	
	15t16	0.001731	0.001811	0.033481	0.005163	...	
	17t18	0.001757	0.000776	0.001840	0.004355	...	
	19	0.000453	0.000200	0.000474	0.001123	...	

region		RoW				\
sector		63	64	J	70	
region	sector					
AUS	AtB	1.143737e-04	5.153717e-09	2.285107e-07	7.786856e-08	
	C	1.226316e-06	1.086802e-07	9.492337e-09	1.571046e-07	
	15t16	9.386042e-06	5.031958e-06	6.040074e-06	4.893121e-06	
	17t18	2.321002e-06	5.746660e-07	2.435455e-06	1.127767e-06	
	19	2.298108e-07	5.689976e-08	2.411432e-07	1.116643e-07	

region						\
sector		71t74	L	M	N	
region	sector					
AUS	AtB	1.517644e-05	4.463792e-06	1.377724e-04	2.552552e-05	
	C	1.873514e-05	4.527246e-07	4.066696e-07	7.050016e-07	
	15t16	3.594692e-05	2.131039e-05	1.922126e-04	1.205233e-04	
	17t18	1.939607e-06	9.390472e-06	1.961856e-06	5.808983e-06	
	19	1.920475e-07	9.297846e-07	1.942504e-07	5.751684e-07	

region			
sector		O	P
region	sector		
AUS	AtB	2.604967e-05	6.252650e-09
	C	1.253368e-06	1.432423e-07

```
15t16   2.022545e-04  1.013494e-06
17t18   6.168260e-06  1.759452e-07
19      6.107418e-07  1.742097e-08

[5 rows x 1435 columns]
```

Alternatively, Pymrio provides a function which iterates through all missing accounts and calculates them:

```
In [10]: wiod.calc_all()

Out[10]: <pymrio.core.mriosystem.IOSystem at 0x7fdeec1827b8>
```

At this point, a basic EE MRIO analysis is accomplished. For example, the regional consumption based accounts of the AIR emissions are now given by:

```
In [11]: wiod.AIR.D_cba_reg

Out[11]: region             AUS           AUT           BEL            BGR  \
         stressor
         CO2       4.404070e+05  1.022100e+05  1.586176e+05   42924.986975
         CH4       4.275465e+06  7.599975e+05  1.030354e+06  464018.748607
         N2O       9.588178e+04  3.086814e+04  4.609171e+04   13203.713081
         NOX       2.359815e+06  3.324339e+05  4.508892e+05  142917.818720
         SOX       2.399335e+06  1.983047e+05  3.702525e+05  400357.951750
         CO        2.173900e+07  1.371366e+06  2.167114e+06  703172.284772
         NMVOC     3.101630e+06  3.582680e+05  5.920832e+05  190582.650539
         NH3       3.851776e+05  9.254548e+04  1.245648e+05   45897.394639

         region             BRA           CAN           CHN            CYP  \
         stressor
         CO2       4.059629e+05  5.659664e+05  5.031700e+06   13943.187686
         CH4       1.352464e+07  4.068558e+06  5.433871e+07  157009.091900
         N2O       5.899229e+05  1.634371e+05  1.831795e+06    3200.309665
         NOX       2.786076e+06  1.904551e+06  1.925370e+07   35972.513098
         SOX       1.699074e+06  2.088103e+06  3.245490e+07   43500.967386
         CO        2.681292e+07  7.525147e+06  9.904520e+07  144686.477852
         NMVOC     5.323333e+06  2.131757e+06  2.016103e+07   43518.270216
         NH3       1.345046e+06  4.204562e+05  6.415339e+06    8931.594745

         region             CZE           DEU      ...            PRT  \
         stressor                                   ...
         CO2       108758.745642  1.054136e+06      ...   7.658922e+04
         CH4       780222.089424  6.668537e+06      ...   8.948877e+05
         N2O        27441.728571  2.914646e+05      ...   3.091511e+04
         NOX       292246.717821  2.701648e+06      ...   3.025544e+05
         SOX       225907.785277  1.951840e+06      ...   1.918064e+05
         CO        829881.093571  1.099191e+07      ...   1.194956e+06
         NMVOC     273912.655126  2.923060e+06      ...   4.003833e+05
```

```
NH3        67224.140441  8.505438e+05      ...       8.987684e+04

region              ROU           RUS            SVK            SVN  \
stressor
CO2        1.173831e+05  1.311461e+06   40459.233377   24251.728341
CH4        1.344168e+06  1.532052e+07  411099.098085  182504.004554
N2O        5.163863e+04  4.422776e+05   13658.674182    7011.741463
NOX        3.380263e+05  4.444685e+06  125333.624730   73379.182597
SOX        4.979996e+05  1.398364e+06  103186.610826   48180.228365
CO         2.055640e+06  2.165403e+07  455232.910264  580264.681074
NMVOC      6.065405e+05  4.179851e+06  138654.031320  142881.841642
NH3        1.911781e+05  7.889417e+05   35515.968170   23476.633339

region              SWE           TUR            TWN            USA            RoW
stressor
CO2        9.434506e+04  3.494179e+05  2.246294e+05  6.210161e+06  5.620778e+06
CH4        7.352664e+05  3.652537e+06  1.104729e+06  3.917121e+07  7.560548e+07
N2O        3.576881e+04  9.538255e+04  3.551477e+04  1.182906e+06  3.590470e+06
NOX        3.524920e+05  1.797639e+06  8.632669e+05  1.845556e+07  3.504645e+07
SOX        2.078760e+05  1.548830e+06  1.075249e+06  1.523013e+07  2.860410e+07
CO         2.048666e+06  4.860666e+06  4.927789e+06  1.005814e+08  3.566157e+08
NMVOC      5.666544e+05  1.738178e+06  1.095519e+06  2.095710e+07  4.208942e+07
NH3        8.488958e+04  5.979386e+05  1.032068e+05  3.090159e+06  8.572543e+06

[8 rows x 41 columns]
```

```
In [12]: wiod.AIR.unit
```

```
Out[12]: unit       unit
         stressor
         CO2          Gg
         CH4           t
         N2O           t
         NOX       undef
         SOX       undef
         CO            t
         NMVOC         t
         NH3           t
```

Pymrio can be linked with the country converter coco to ease the aggregation of MRIO and results into different classifications. Using the country converter, WIOD can be aggregated into EU and non-EU countries with singling out Germany by:

```
In [13]: import country_converter as coco
         wiod.aggregate(region_agg = coco.agg_conc(original_countries='WIOD',
                                                   aggregates=[{'DEU': 'DEU', 'GBR':'GBR'}, 'EU
                                                   missing_countries='Other',
                                                   merge_multiple_string=None))
```

```
Out[13]: <pymrio.core.mriosystem.IOSystem at 0x7fdeec1827b8>
```

We rename the EU account to reflect that is does not include Germany:

```
In [14]: wiod.rename_regions({'EU':'Rest of EU'})
```

```
Out[14]: <pymrio.core.mriosystem.IOSystem at 0x7fdeec1827b8>
```

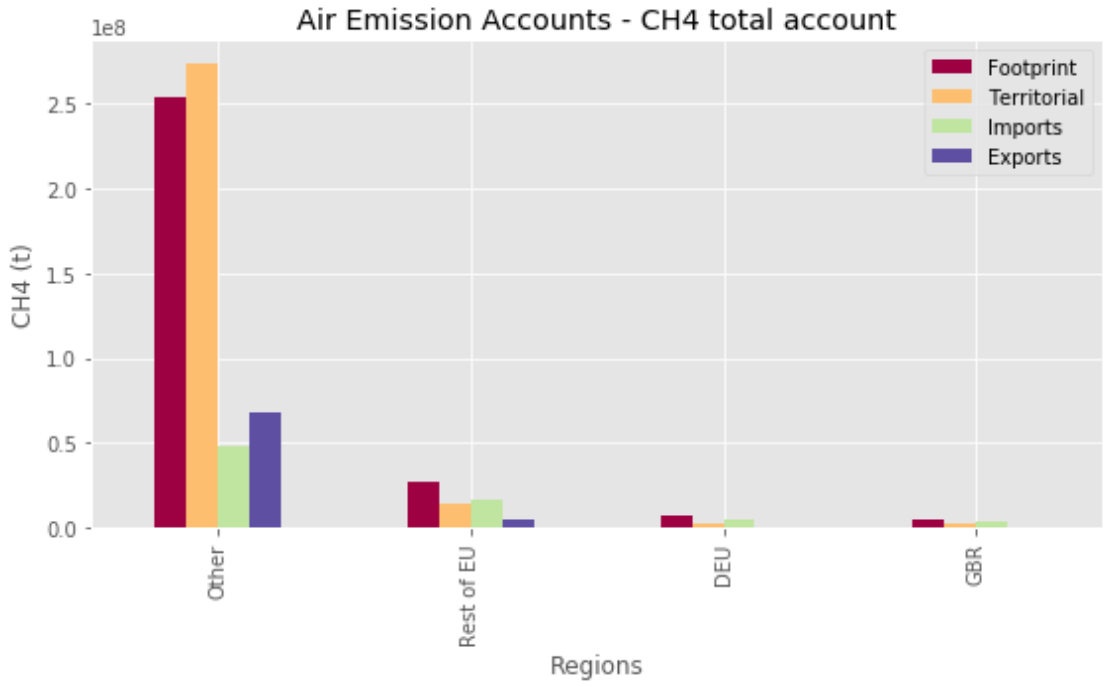
The regional footprint account are now:

```
In [15]: wiod.AIR.D_cba_reg
```

```
Out[15]: region           Other    Rest of EU           DEU           GBR
         stressor
         CO2       2.436179e+07  3.472823e+06  1.054136e+06  7.397044e+05
         CH4       2.540661e+08  2.711250e+07  6.668537e+06  5.235498e+06
         N2O       9.705186e+06  1.128531e+06  2.914646e+05  2.118832e+05
         NOX       1.043111e+08  1.093267e+07  2.701648e+06  2.164933e+06
         SOX       1.037493e+08  8.344435e+06  1.951840e+06  1.421854e+06
         CO        7.661455e+08  5.466639e+07  1.099191e+07  1.068169e+07
         NMVOC     1.280392e+08  1.577316e+07  2.923060e+06  2.986943e+06
         NH3       2.672782e+07  3.493227e+06  8.505438e+05  5.900984e+05
```

To visualize for example the CH4 accounts:

```
In [16]: import matplotlib.pyplot as plt
         with plt.style.context('ggplot'):
             wiod.AIR.plot_account('CH4', figsize=(8,5))
             plt.savefig('/tmp/wiod/airch4.png', dpi=300)
             plt.show()
```



To calculate the source (in terms of regions and sectors) of a certain stressor or impact driven by consumption, one needs to diagonalize this stressor/impact. This can be done with Pymrio by:

```
In [17]: diag_CH4 = wiod.AIR.diag_stressor('CH4')
```

and be reassigned to the aggregated WIOD system:

```
In [18]: wiod.CH4_source = diag_CH4
```

In the next step the automatic calculation routine of Pymrio is called again to compute the missing accounts in this new extension: and be reassigned to the aggregated WIOD system:

```
In [19]: wiod.calc_all()
```

```
Out[19]: <pymrio.core.mriosystem.IOSystem at 0x7fdeec1827b8>
```

The diagonalized CH4 data now shows the source and destination of the specified stressor (CH4):

```
In [20]: wiod.CH4_source.D_cba.head()
```

```
Out[20]: region                Other                                          \
         sector                  AtB             C         15t16         17t18
         region sector
         Other  AtB     6.120041e+07  8.455234e+04  3.658411e+07  2.988418e+06
                C       1.008359e+06  6.714292e+06  2.047332e+06  6.420307e+05
                15t16   3.968202e+03  6.218228e+01  8.736127e+04  5.178453e+02
                17t18   9.369869e+01  2.287802e+01  2.464623e+02  1.185856e+04
                19      5.587156e+00  1.040420e+00  1.268140e+01  1.252185e+02

         region                                                                \
         sector                    19             20          21t22            23
         region sector
         Other  AtB     867172.684194  230646.602537  441913.627992  1.766666e+05
                C       117665.005135   33160.714629  281538.575874  5.643346e+06
                15t16      639.802755      24.298048     128.945944  1.099366e+02
                17t18      200.126039       4.500219      68.017013  3.330082e+01
                19        1231.987687       0.344568       4.205279  1.580128e+00

         region                                      ...             GBR  \
         sector                    24             25   ...              63
         region sector                                ...
         Other  AtB     6.045454e+05  197135.975631   ...      669.903691
                C       1.564758e+06  231675.430540   ...     1405.758158
                15t16   4.216024e+02      83.091425   ...        0.460965
                17t18   7.862589e+01      59.680321   ...        0.093075
                19      4.194052e+00       3.043624   ...        0.008632
```

```
region                                                                  \
sector                    64             J            70         71t74
region sector
Other  AtB       3406.973739   8805.678036   6656.233633  4123.121986
       C         9357.742729  20287.540899  18680.219527  8586.783042
       15t16        3.215184      8.818689      5.805941     3.871073
       17t18        0.848278      1.738428      1.444981     0.919367
       19           0.117312      0.225215      0.171093     0.106037

region                                                                   \
sector                     L             M             N             O
region sector
Other  AtB       19984.727842   9398.054711  44359.672517  12305.895420
       C         49408.298618  15853.401016  93562.146555  23512.720979
       15t16        18.671491      8.695184     44.370659     11.707402
       17t18         6.608830      2.031215     12.658218      3.765588
       19            1.104701      0.343349      1.430827      0.646012

region
sector                 P
region sector
Other  AtB       3.055303
       C         4.041194
       15t16     0.001748
       17t18     0.001256
       19        0.000075

[5 rows x 140 columns]
```

In this square footprint matrix, every column represents the amount of stressor occurring in each region - sector driven by the consumption stated in the column header. Conversly, each row states where the stressor impacts occurring in the row are distributed due (from where they are driven).

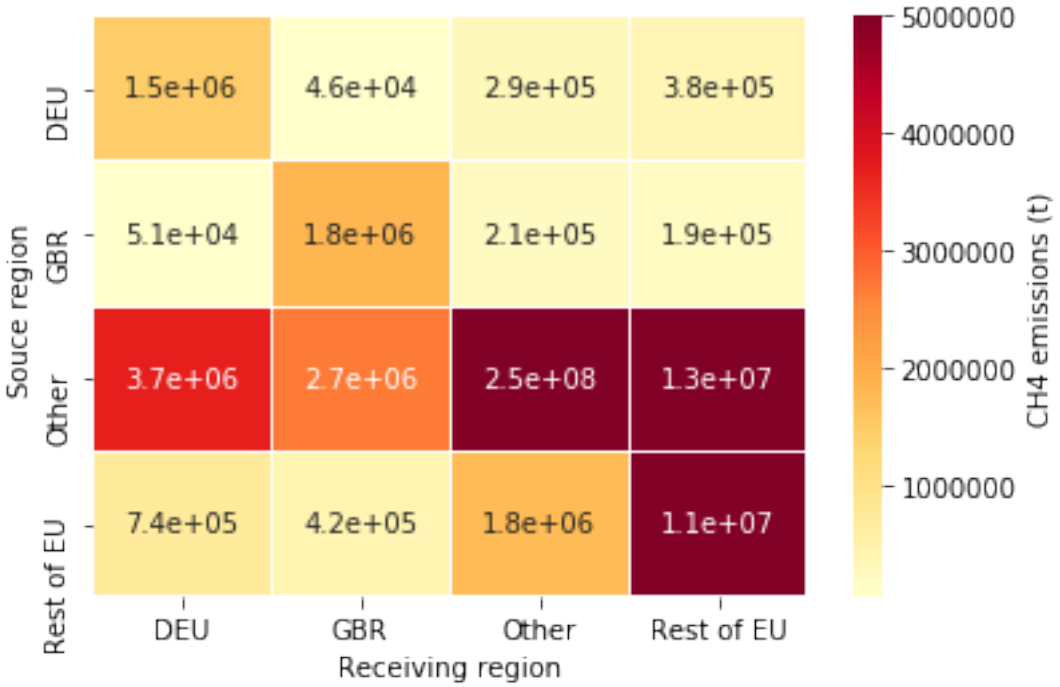
```
In [21]: CH4_source_reg = wiod.CH4_source.D_cba.groupby(
             level='region', axis=0).sum().groupby(
             level='region', axis=1).sum()

In [22]: CH4_source_reg
```

```
Out[22]: region               DEU           GBR         Other    Rest of EU
         region
         DEU         1.485343e+06  4.634238e+04  2.892830e+05  3.819713e+05
         GBR         5.139252e+04  1.833541e+06  2.112405e+05  1.879226e+05
         Other       3.696832e+06  2.711860e+06  2.457410e+08  1.317725e+07
         Rest of EU  7.402886e+05  4.186665e+05  1.756700e+06  1.128755e+07
```

```
In [23]: import seaborn as sns
         CH4_source_reg.columns.name = 'Receiving region'
```

```
CH4_source_reg.index.name = 'Souce region'
sns.heatmap(CH4_source_reg, vmax=5E6,
            annot=True, cmap='YlOrRd', linewidths=0.1,
            cbar_kws={'label': 'CH4 emissions ({})'.format(wiod.CH4_source.unit.unit[
plt.savefig('/tmp/wiod/airch4_source_reg.png', dpi=300)
plt.show()
```



Storing the MRIO database can be done with

```
In [24]: storage_path = '/tmp/wiod/aly'
         wiod.save_all(storage_path)

Out[24]: <pymrio.core.mriosystem.IOSystem at 0x7fdeec1827b8>
```

From where it can be received subsequently by:

```
In [25]: wiod = pymrio.load_all(storage_path)
```

The meta attribute of Pymrio mentioned at the beginning kept track of all modifications of the system. This can be shown with:

```
In [26]: wiod.meta

Out[26]: Description: WIOD metadata file for pymrio
         MRIO Name: WIOD
         System: industry-by-industry
```

```
Version: data13
File: /tmp/wiod/aly/metadata.json
History:
20181023 11:51:34 - FILEIO -  Added satellite account from /tmp/wiod/aly/factor_inputs
20181023 11:51:34 - FILEIO -  Added satellite account from /tmp/wiod/aly/SEA
20181023 11:51:34 - FILEIO -  Added satellite account from /tmp/wiod/aly/AIR
20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/CO2
20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/EM
20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/EU
20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/lan
20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/mat
20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/wat
20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/CH4_source
 ... (more lines in history)
```

Custom notes can be added to the meta with:

```
In [27]: wiod.meta.note("Custom note")
```

The history of the meta data can be filtered for specific entries like:

```
In [28]: wiod.meta.file_io_history
```

```
Out[28]: ['20181023 11:51:34 - FILEIO -  Added satellite account from /tmp/wiod/aly/factor_inpu
          '20181023 11:51:34 - FILEIO -  Added satellite account from /tmp/wiod/aly/SEA',
          '20181023 11:51:34 - FILEIO -  Added satellite account from /tmp/wiod/aly/AIR',
          '20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/CO2',
          '20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/EM',
          '20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/EU',
          '20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/lan',
          '20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/mat',
          '20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/wat',
          '20181023 11:51:33 - FILEIO -  Added satellite account from /tmp/wiod/aly/CH4_source
          '20181023 11:51:33 - FILEIO -  Loaded IO system from /tmp/wiod/aly',
          '20181023 11:51:32 - FILEIO -  Saved WIOD to /tmp/wiod/aly',
          '20181023 11:51:28 - FILEIO -  Extension wat parsed from /tmp/wiod/raw',
          '20181023 11:51:27 - FILEIO -  Extension mat parsed from /tmp/wiod/raw',
          '20181023 11:51:26 - FILEIO -  Extension lan parsed from /tmp/wiod/raw',
          '20181023 11:51:26 - FILEIO -  Extension EU parsed from /tmp/wiod/raw',
          '20181023 11:51:24 - FILEIO -  Extension EM parsed from /tmp/wiod/raw',
          '20181023 11:51:22 - FILEIO -  Extension CO2 parsed from /tmp/wiod/raw',
          '20181023 11:51:21 - FILEIO -  Extension AIR parsed from /tmp/wiod/raw',
          '20181023 11:51:19 - FILEIO -  SEA file extension parsed from /tmp/wiod/raw',
          '20181023 11:51:13 - FILEIO -  WIOD data parsed from /tmp/wiod/raw/wiot08_row_sep12.
          '20181023 11:50:53 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/wate
          '20181023 11:50:52 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/mate
          '20181023 11:50:52 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/land/
          '20181023 11:50:52 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/AIR/A
          '20181023 11:50:51 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/CO2/C
```

```
'20181023 11:50:50 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/EM/EI
'20181023 11:50:49 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/EU/EU
'20181023 11:50:48 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/SEA/W
'20181023 11:50:48 - FILEIO -  Downloaded http://www.wiod.org/protected3/data13/updat
```

This tutorial gave a short overview about the basic functionality of Pymrio. For more information about the capabilities of pymrio check the online documentation.