Developing a Hazardous Waste Management Infrastructure Plan (HWMIP) for the Province Zhejiang

During 2006 - 2007 the Sino-German Collaboration Program 'Environmental Enterprise Consultancy Zhejiang' (EECZ) has elaborated, on request and in collaboration with its Chinese counterparts, a 'Hazardous Waste Management Infrastructure Plan' (HWMIP) for the Chinese Province Zhejiang (See Fig. 1. Planning work was executed at the 'Zhejiang Environmental Protection Bureau' (ZEPB) in cooperation with the Zhejiang Solid Waste Management Department. The plan provides a compilation of information for decision makers to set the course for the development of the future infrastructure required for managing industrial hazardous waste in Zhejiang.

The planning work can be divided into four phases:

(1) Taking stock of the present situation with regard to industrial hazardous waste in Zhejiang
(2) Estimating future hazardous waste generation and corresponding treatment- and disposal capacity requirements
(3) Developing options for the potential future infrastructure
(4) Evaluating the options with regard to environmental impact and economical viability

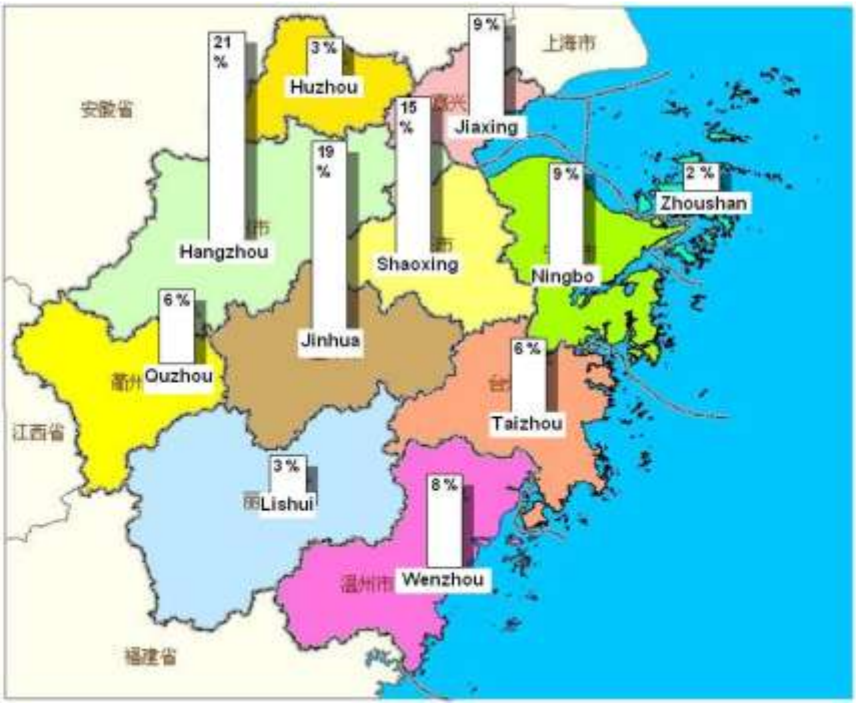

Fig. 1: Share of Zhejiang's 11 Cities in industrial hazardous waste generation in

2004 according to official data (total HW generation: 378,000 t/a)[1]

1.1. Taking stock of the present situation

At the outset, the current inventory with regard to hazardous waste generation, recovery and disposal in Zhejiang had to be established. At the time when the planning work was undertaken, the official assessment of HW generation was based on the so-called HW declaration data. Registered HW generators are obliged to report annually their hazardous waste generation, recovery and disposal to the competent authorities who use these data subsequently for their statistics. However, these data are not further verified. Only medium and large scale entities are registered for HW generation. Hazardous waste generation from small and micro scale establishments, though having a major share in overall HW generation, is not considered.

Arriving at realistic data for the hazardous waste inventory proved to be extremely difficult under these circumstances. After many discussions it was decided to refer the inventory not to actual hazardous waste *generation*, but to hazardous waste *declaration* (which would be significantly lower than actual HW generation).Taking note of the fact that only officially declared waste is “visible” and can be subjected to HW legislation and is available for recovery and disposal. Similarly the hazardous waste forecast would be based on HW *declaration* rather than on actual *generation* while assuming that the gap between declared and actually generated hazardous waste would gradually narrow with the time passing due to improved regulatory tools and practical enforcement skills of the competent authorities.Table 1 shows a summary of the waste declaration data from 2004 on which the inventory is based. The data are differentiated according to the 11 cities in Zhejiang. Thereafter 2,950 registered waste procures have declared a total HW amount of 378,000 t/a. However, an analysis of the characteristic economic data of Zhejiang’s industrial sectors over the last year’s leads to the conclusion that the HW quantities declared by the waste procures are too low. Actual hazardous waste generation is probably 80 % higher and closer to 680,000 t/a.[2] The gap results from incorrect classification, non-reported waste types, and non-registered waste producers. Another important reason for lack of notification of hazardous waste is that, many hazardous waste producers consider their hazardous residues as commercial goods rather than as hazardous waste when selling such waste to third parties for recovery, thus bypassing hazardous waste legislation.

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[1] Zhejiang Environmental Protection Bureau, 2006
[2] Only hazardous waste from primary sources; the estimation does not include waste from secondary sources, waste from remediation of contaminated sites and waste from spent/discarded products (e. g. WEEE)

Table 1: Generation, recycling/recovery, disposal, discharge and storage of HW in Zhejiang's 11 Cities according to HW declaration data 2004

City	Generation	Utiliz. & Recovery		Disposal		Discharge		Storage	
	[t/a]	[t/a]	[%]	[t/a]	[%]	[t/a]	[%]	[t/a]	[%]
Hangzhou	78,056	34,215	44	42,005	54	628	0.8	1,623	2.1
Ningbo	34,315	30,068	88	4,027	12	142	0.4	61	0.2
Wenzhou	29,143	12,951	44	6,801	23	1,804	6.2	7,591	26.0
Jiaxing	34,167	29,893	87	4,325	13	0	0.0	2	0.0
Houzhou	11,851	10,454	88	50	0	1,325	11.2	21	0.2
Shaoxing	55,798	51,961	93	3,795	7	3	0.0	39	0.1
Jinhua	73,288	71,385	97	1,799	2	50	0.1	50	0.1
Quzhou	21,727	20,875	96	844	4	8	0.0	3	0.0
Zhoushan	7,037	2,196	31	3,552	50	20	0.3	1,278	18.2
Taizhou	22,052	16,446	75	4,902	22	578	2.6	106	0.5
Lishui	10,516	10,312	98	171	2	28	0.3	5	0.0
Total	**377,950**	**290,756**	**77**	**72,271**	**19**	**4,586**	**1.2**	**10,779**	**2.9**

As can be seen from Table 1, the HW recovery rate is extremely high with 77 %. However, this figure does not comply with the installed licensed capacity of facilities for recycling/recovery in

Zhejiang. Moreover, in relation to the Chinese average recycling/recovery rate and to data from comparable states, this recycling/recovery rate is very high and uncharacteristic for regions undergoing fast economic growth. Therefore, the indication of 77% value is highly doubtful.[3]

The disposal situation is determined by an insufficient capacity of treatment facilities. The installations presently in place are predominantly small-scale incinerators which do not meet modern state-of-the-art requirements. New facilities – landfills and incinerators with small capacities – are already in the planning and construction stage.

1.2. Prognosis of Future HW Generation

By applying the concept of "influencing factors", the 2004 waste declaration data have been extrapolated to 2010, 2015 and eventually 2020 (See Table 2). The influencing factors reflect and differentiate a variety of complex impacts that are known to affect HW generation.

Table 2: Influencing factors affecting hazardous waste declaration in Zhejiang

[3] In 2006 the average utilization rate of hazardous waste amongst the EU-15 Member States approximated only 28%

Factor	2004 - 2010	2011 - 2015	2016 - 2020
Law enforcement	1.04	1.05	1.02
Categorization/classification	1.09	1.05	1.00
Prevention/minimization	1.00	0.96	0.90
Knowledge/awareness	1.025	1.03	1.01
Consideration of SSE	1.10	1.07	1.02
Economic development	1.19	1.15	1.12
Specific industrial impacts	1.04	1.02	1.01
Secondary environmental measures	1.07	1.04	1.02
Quality standards	1.03	1.02	1.00
Disposal options	1.02	1.04	1.03
Resulting overall factor	**1.605**	**1.43**	**1.13**
Variance	+/- 12 %	+/- 12.5 %	+/- 15 %

Fig. 2 shows the forecasted generation of primary industrial hazardous waste in Zhejiang until 2020. HW generation (precisely: HW declaration) from primary sources is estimated to grow from 378,000 t/a in 2004 to 607,000 t/a in 2010 to 868.000 t/a in 2015 to 980,000 t/a in 2020. Error bars give an indication of the precision range. Main driver of the forecasted rise in HW generation is Zhejiang's anticipated strong economic growth.

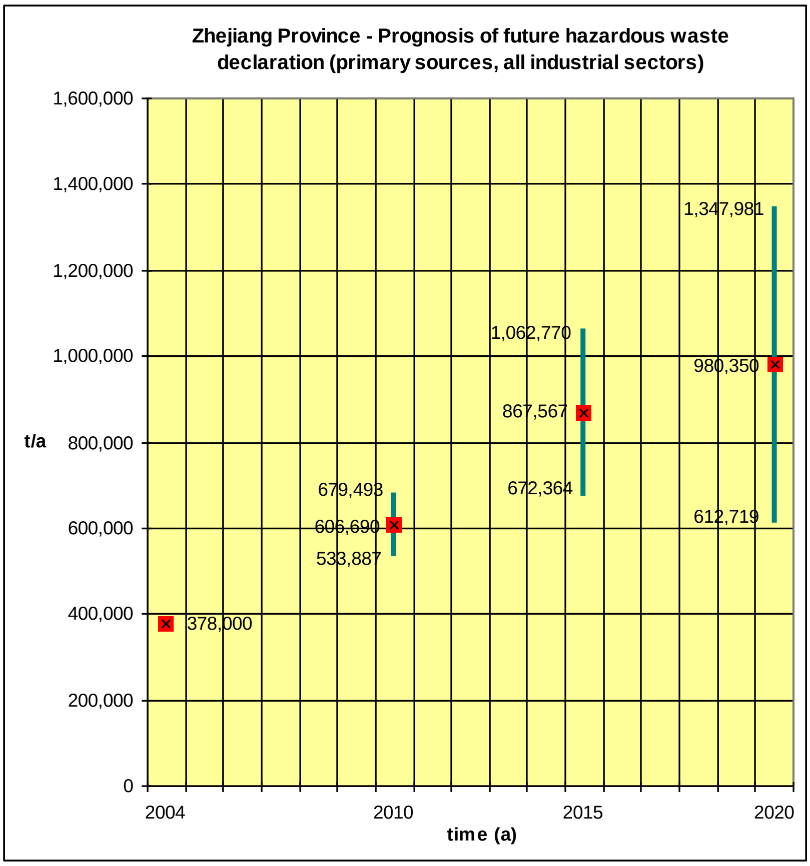

Fig. 2: Prognosis of future HW Declaration in Zhejiang Province

1.3. Assessment of Future Treatment and Disposal Capacity Needs

With regard to waste treatment and disposal the following options have been considered in the plan:

- Recycling/Recovery
- Treatment
  - Chemical / physical treatment (CPT)
  - Incineration
  - Landfill

It is understood that "recycling and recovery" comprises material recovery (recycling) and energy recovery (recovery) from waste with sufficiently high calorific value (e.g. co-processing in cement kilns).

Further to recycling/recovery it has been assumed that, with on-going plan implementation, the dubiously high recycling/recovery rate of 77% from 2004 will converge to a more reasonable and realistic value of 50 % by 2010 and 45 % by 2020. Though the recycling/recovery rate would decrease in this case, recycling/recovery quantities in absolute numbers increases actually, based on the prognosis data (See Fig. 3). Details for recycling/recovery have not been further elaborated. The assumption is that recycling/recovery will be market driven while the regulator limits his role to ensure protection of environment and human health by providing and enforcing appropriate standards related to recycling/recovery.

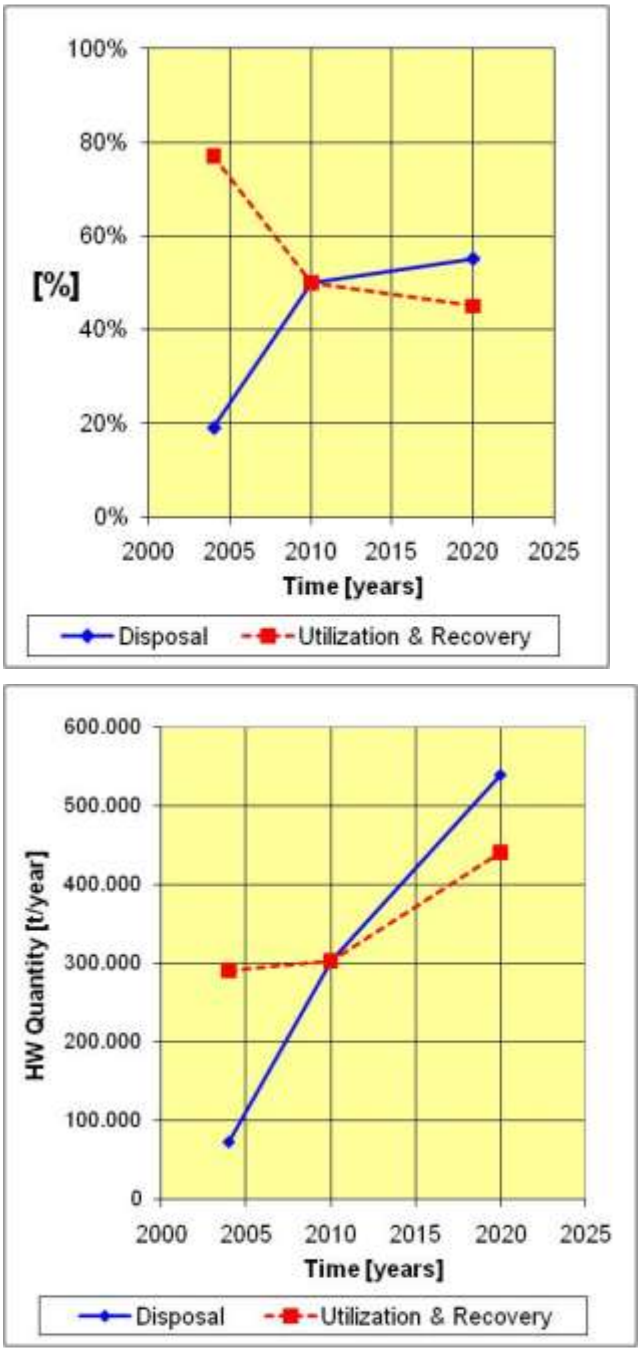

Fig. 3: Shares of hazardous waste recycling/recovery in percent of total primary hazardous waste generation (left figure) and in absolute numbers (right figure) for 2004 (baseline scenario) and for 2010 and 2020 (anticipated)

In order to quantify the waste streams that have to be allocated to the various disposal options such as chemical/physical treatment, incineration and landfill, the forecasted HW declaration data for generation have been further detailed with regard to the originating industrial sectors in Zhejiang, categorized into three classes “inorganic/organic”, ‘inorganic’ and ’organic’ and eventually allocated to the different disposal options. This was done by referring to a special version of the European Waste List that specifies options for CPT, incineration and landfill for the waste types generated by the different industrial sectors.

Declaration data consider only *primary* wastes, i.e. production process related waste. On top of the *primary* wastes, however, also *secondary* waste generation has to be considered in the future infrastructure. Waste from secondary sources is defined as waste originating from recycling/recovery as well as from disposal operations, such as chemical/physical treatment, incineration, and landfill. Secondary waste generation was estimated (Ref. chapter 13.4.2) and considered for the assessment of the disposal capacities.

Fig. 4 is a Sankey diagram and depicts the material flow of the estimated future primary and secondary HW streams with regard to recycling/recovery, chemical/physical treatment, incineration and landfill in 2020. Table 3 gives a summary of the estimated disposal capacities and other relevant data for 2010 and 2020.

Table 3: Estimated capacities for chemical/physical treatment, incineration and landfill of primary and secondary hazardous waste required in Zhejiang in 2010 and 2020 (Assumption: 50% and 45% of primary hazardous waste generated will be absorbed by recycling & recovery in 2010 and 2020 respectively)

	2004 (baseline) [t / year]	**2010 [t / year]**	**2020 [t / year]**
Primary hazardous waste generation	378,000	607,000	980,000
Total primary & secondary HW generation	- not available -	776,000	1,222,000
Disposal, total	87,000	465,000	771,000
Chem. / phys. Treatment		152,000	196,000
Incineration		122,000	189,000
Landfill		191,000	386,000
Absorbed by recycling & recovery	291,000	311,000	451,000

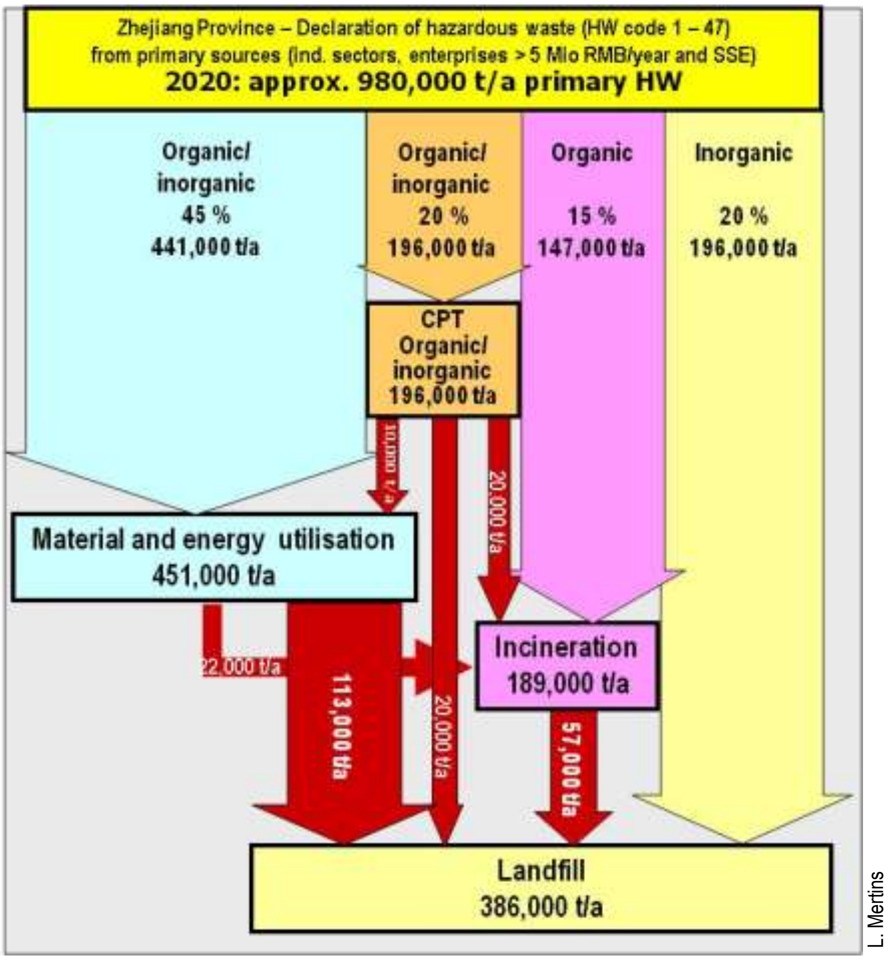

Fig. 4:Sankey diagram showing quantities and flow of primary and secondary hazardous wastes of a hazardous waste management scenario (secondary wastes shaded red)

The procedure described above was repeated for every city, using the declaration data for hazardous waste generation of the respective cities of 2004 as a baseline. At this planning stage, as a first approximation, identical influencing factors and shares for recycling and recovery were assumed for all cities.

1.4. Four Alternatives for the Potential Future Infrastructure for HW Treatment & Disposal in Zhejiang Province

The need for ecological as well as economical viability of the future HWM infrastructure would call for joint action of all stakeholders. However, the situation in Zhejiang Province was in strong contradiction to a coordinated planning approach: There was neither co-operation nor even an understanding between the cities with regard to joint operation of waste management facilities. Each city strived to set up its own small-scale incinerator, landfill site and other treatment facilities.

In order to illustrate this situation and to quantify its repercussions, four alternative approaches have been developed where each alternative stands for a specific spatial pattern of grouping cities to clusters with regard to waste generation with each alternative representing therefore a different level of centralization for the future infrastructure.

Centralization in this context means providing the required waste treatment capacity by a small number of large-scale facilities rather than by a large number of small-scale facilities. Pollution control and economical viability of incinerators and landfill sites become usually more favorable with increasing scale of such units. Particularly the ‘economy of scale’ effect of expensive incinerators and landfill sites plays an important role in this context. A disadvantage of a centralized infrastructure is the higher overall transport distance, compared to a decentralized infrastructure, due to the larger catchment area for waste collection and transport. Environmental and economical implications for hazardous waste transport have to be taken into consideration therefore when comparing centralized and decentralized solutions. In view of the excellent road infrastructure of Zhejiang Province however (all cities and major towns are interlinked by a toll-based 4-6 lane highway system), it was assumed that differences of the environmental impact of hazardous waste transport with regard to centralization are negligible at this stage and have not been further investigated.

Alternative 1 represents a completely decentralized approach in which each of the 11 Cities would get a complete set of treatment & disposal facilities consisting of a chemical physical treatment (CPT) plant, an incinerator and a landfill (See Fig. 5). This alternative corresponds best to the ideas of many of Zhejiang’s city-level planners. At the other end, alternative 4 marks the highest level of centralization and provides expensive incinerators and landfills only to three main clusters where HW generation is concentrated (CPT plants still in each City). The fourth alternative must be seen as an “ideal” solution because it was not in line with the status of ongoing facility development. It is used therefore only as a baseline and serves as a reference for the highest level of centralization.

The other two alternatives that have been elaborated are intermediates between the first and the fourth one. They take account of the actual status of facility development as well as of the presetting given by the National Hazardous Waste Management Plan of China's then 'State Environmental Protection Agency' (SEPA). Alternative 2 represents a "moderately centralized" infrastructure; alternative 3 is "more centralized". The alternatives 1-4 are arranged in such a way that their sequence presents an increasing level of centralization.

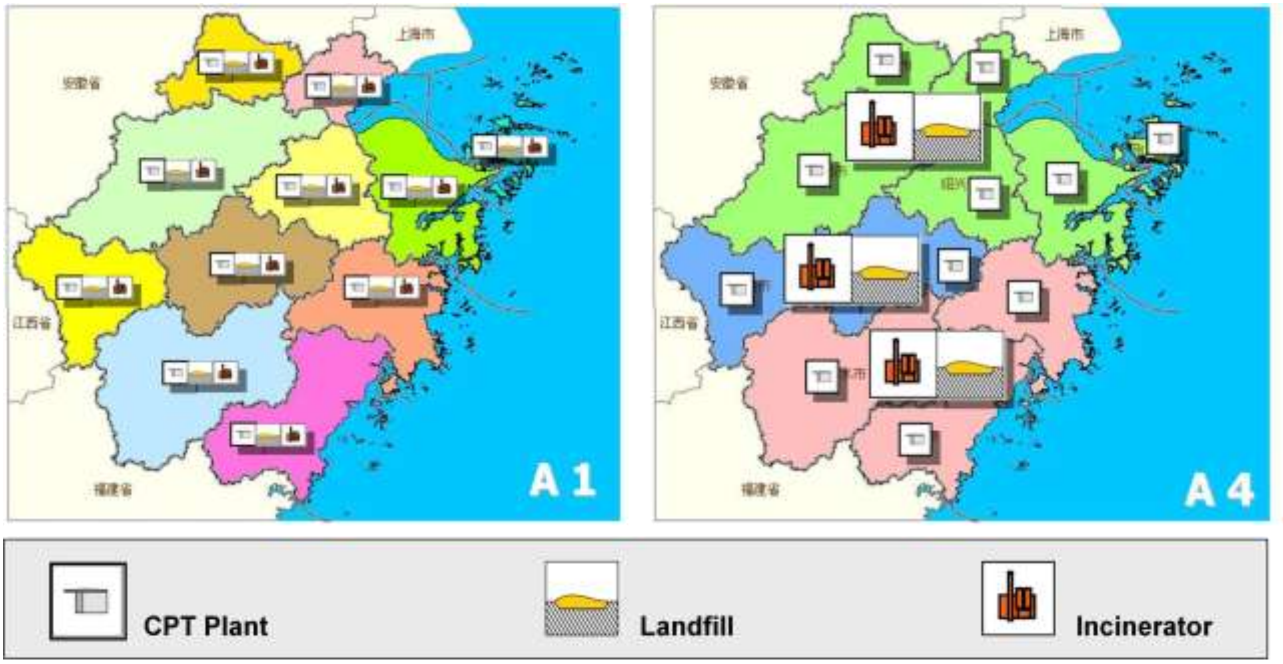

Fig. 5: Alternative 1 (Decentralized infrastructure: All 11 cities equipped with one CPT plant, incinerator and landfill site)
Alternative 4 (Centralized infrastructure: All 11 cities grouped into 3 clusters and each cluster equipped with one centralized landfill site and incinerator, while every city has yet one CPT plant)

1.5. Results

1.5.1. Economical ranking of alternatives

The investment requirements have been calculated for the four alternatives taking into account the respective numbers and capacities of CPT plants, incinerators and landfill sites[4] for each alternative (Table 4).

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4 For landfill sites an operation period of 20 years is adopted, calculations assume that construction would be completed latest by 2010

As the data clearly show, the total investment costs of all three centralized alternatives are significantly lower than the costs of the decentralized alternative 1. This is caused by substantial "economy of scale" effects particularly in case of incinerators but also landfill sites.

Table 5 shows the total annual operation costs of the four alternatives including capital-, variable and fixed operating costs as well as additional transport costs for 2010 and 2020. The annual capital costs are based on an amortization period of 15 years and interest rates of 8 %/a.

Regarding total annual operation costs the advantage of the centralized alternatives is less obvious than in case of the investment costs shown in the previous table. This is because additional transport costs reduce the benefit of centralization to a certain extent: With rising centralization level additional transport distances increase and so do transport costs. However, the total annual costs of a completely decentralized solution (A1) would be still significantly higher than the costs of the centralized scenarios.

Table 4 Investment requirements for the four alternatives

Alternative	Chem./Phys. Treatm.		Incineration		Landfill		Total	
	No of CPTP's	Total [Mio RMB[5]]	No of Inciner.	Total [Mio RMB]	No of Landf.	Total [Mio RMB]	Total [Mio RMB]	[%]
A 1 (decentralized)	11	285	11	2,087	11	712	3,084	180 %
A 2 (moder. central.)	11	285	5	1,180	5	516	1,981	116 %
A 3 (more central.)	11	285	4	1,067	4	456	1,808	106 %
A 4 (centralized)	**11**	**285**	**3**	**1,004**	**3**	**424**	**1,713**	**100 %**

Given the present status of facility development it appears that alternatives 2 and 3 have a realistic chance for implementation. However coordinated planning should be initiated soon, otherwise more cities may start planning according to their own requirements and realization of a centralized approach becomes more difficult.

Table 5 Total annual operation costs for the four alternatives including capital-, variable & fixed operating- and additional transport costs in 2010 and 2020

Alternative	2010	2020

[5] RMB = Renminbi **is the currency in China, the abbreviation is** *CNY*, but in China is used the abbreviation RMB , the symbol is ¥. The units of the currency are the *Yuán.*

	[Mio RMB / year]	[%]	[Mio RMB / year]	[%]
A 1 (decentralized)	575	127 %	1,000	138 %
A 2 (moder. central.)	496	110 %	773	106 %
A 3 (more central.)	483	107 %	725	99.9 %
A 4 (centralized)	**452**	**100 %**	**726**	**100 %**

1.5.2. Conclusion related to chemical/physical treatment

Most HW types to be allocated to chemical/physical treatment have a high average water content which can be separated by treatment. This reduces significantly the quantity of the remaining secondary waste for further transport, utilization and treatment (e.g. incineration) or final disposal at a landfill. Moreover, CPT plants are important links in the HW logistics chain and can serve as collection points and temporary-storage facilities for other waste types that do not require CPT. At CPT plants, such waste types can be collected, packed and prepared for transport to centralized incinerators and landfill sites located elsewhere.

CPT plants are relatively low in investment; there is no “economy of scale” effect and economically viable operation of small scale installations is feasible.

CPT facilities should be planned therefore for every
city.

1.5.3. Conclusion related to incineration

Based on the assessment of the alternatives and in due consideration of the transportation costs, it is recommended to implement initially a system with centralized incinerators. At a later stage it has to be decided if the expected future capacity requirements will be met by either developing additional incinerators or by enhancing the capacities of existing incinerators. When making a choice between these two options it should be considered that adding another incineration line to an existing incinerator has the benefit that the infrastructure already available can be used without high additional investments.

With regard to site selection, it is recommended to locate the incinerators near to the industrial zones and close to the waste generating industry, if possible. Existing infrastructure can be used.

The steam produced by energy recovery from the incinerator can be directly utilized as process steam in the adjacent industries. Electricity generation is also possible; however this is less economical than the direct use of steam.

To optimize HW transport to the centralized incinerators, it is recommended to install in each city HW collection points/transfer stations. These collection points might be combined with CPT facilities which are recommended for each city.

The HW incinerators may also serve for healthcare waste disposal. Creating a synergistic effect of integrated waste management, the infrastructure for industrial HW disposal can be combined with the infrastructure for healthcare waste disposal.

1.5.4. Conclusion related to landfill disposal

The total capacity of landfills presently earmarked for the project region is completely insufficient compared to the expected future HW quantities that have to be allocated to landfill disposal.

Based on the assessment of the alternatives and in due consideration of the transportation costs it is recommended to implement a system with initially four centralized landfills. In addition to the three landfill sites in Hangzhou, Ningbo and Taizhou, that are presently under construction, commissioning and planning respectively, a fourth centralized landfill site may cater to the needs of Wenzhou, Quzhou, Jinhua and Lishui.

With regard to site selection it is generally recommended to locate the landfills close to the waste generating industry. However based on the availability of sites and considering the currently relatively low transportation costs, landfill site locations can be also identified outside the centers of waste generation. Further development of landfill facilities after exhausting the capacities of the first sites depends primarily on the availability of site locations with sufficient capacity.

To optimize the transport to the installations it is recommended to install collection points / transfer stations for small quantities. These collection points may be combined with CPT facilities which are recommended for every city.

1.2. Impact

The planning report elaborated under the EECZ-Program has served as a valuable resource of information and data for the Chinese planners of the “Zhejiang Provincial Development, Planning & Research Institute” which is in charge for the development of the official Chinese infrastructure plan. The Planning Institute had submitted the Chinese plan to the "Zhejiang Development and Reform Commission" for approval.

Chinese planners have embraced EECZ's major concern to plan a centralized HWM infrastructure in Zhejiang. The formulation in the official Chinese text however is a recommendation rather than an advice. It was learnt that the 'Zhejiang Development and Reform Commission' (ZDRC) did not find itself in a position to approve a more stringent formulation. *Advising* the cities to undertake facility development jointly would interfere with the Chinese hierarchy principle and violate the autonomous rights of the cities. At the time when the EECZ Program was terminated, the plan had been approved by the ZDRC; however it was not clear as to which extent the concerned Cities would follow the recommendations made.

Taking joint action and crossing city borders in provincial infrastructure development is a rather new concept for Chinese planners. However during the elaboration of the EECZ plan which involved many discussions between Chinese counterparts and German experts, the competent departments in Zhejiang, at the provincial as well at the city level, took on board the concept of a centralized infrastructure for HWM. The EECZ plan was also appreciated by the competent authority at the national level who had forwarded the plan to other Chinese provinces for consideration as an example to follow.