中国可再生能源发展战略国际研讨会

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清华大学核能与新能源技术研究院

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促进可再生能源大规模发展的战略与政策

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开发利用可再生能源是我国建立可持续能源体系，实现能源永继利用的根本出路，也是我国实施可持续发展的重要领域。可再生能源技术是我国战略必争的高新技术领域，其核心技术将反映一个国家的综合竞争能力。大力促进可再生能源的开发利用，掌握具有自主知识产权的核心技术，应该成为我国中长期能源战略和中长期科技规划中重要的优先领域。

可再生能源涵盖的范围，国际上不同的研究场合有不同定义。本研究所涉及的可再生能源领域，主要指风能、太阳能、小水电（电站装机容量不超过 5 万千瓦），生物质能（不包括传统燃烧方式利用秸秆、薪柴、人畜粪便等）、地热能和地温热源热能、海洋能以及其他可以从自然界直接获取的、可再生的、非化石能源。

一、大力发展可再生能源的重要意义

1.1 适应世界范围内可再生能源快速发展的形势，尽快缩小与发达国家的差距，促进可再生能源产业发展和能源领域的技术创新。

当前，世界范围内可再生能源技术发展迅速。全球过去几年内风电和光伏发电的年增长率均高达 30%以上，欧盟风电发电成本过去 5 年间下降了 20%，已经可以与常规电站竞争，进入了大规模发展阶段。太阳能光伏发电比投资预计到 2020 年可降至 1 美元/峰瓦，进入商业化推广阶段。我国可再生能源的开发利用已经有相当的基础，2002 年小水电装机 2840 千瓦，风电 40 万千瓦，生物质发电 100 万千瓦。太阳能热水器已安装 4000 万平方米，居世界第一。小水电技术居于世界先进水平（发达国家水电资源基本开发完毕），风力发电产业开始起步，生物质发电技术已趋成熟，但总体技术水平、发电成本与世界先进水平相比尚有差距。我国应抓住机遇，采用自主研发与成套引进相结合的方式，实现可再生能源技术和产业的跨越式发展。

1.2　开发和利用可再生能源是我国缓解资源瓶颈性约束和环境污染压力，保证能源可持续供应以及促进经济、社会可持续发展的根本出路

我国当前面临能源供应短缺和环境污染两大压力。我国到 2020 年实现 GDP 比 2000 年翻两番的发展目标，能源需求量将达到 25~33 亿吨标准煤。届时，我国能源资源供应不仅总量上面临更大压力，而且石油的进口依存度将超过 60%，

能源供应安全将面临极大的挑战。我国以煤炭为主的能源消费结构，也造成了严重的环境污染，SO_2、NOx、粉尘等大气污染的 70%～90%来自煤炭燃烧，酸雨面积已占全国的 1/3，大气污染造成的经济损失已相当于 GDP 的 2%～3%。世界范围而言，化石燃料消费形成的 CO_2排放，是造成全球气候变暖的主要原因。我国 2000 年的 CO_2排放占世界的 13%，2030 年左右有可能超过美国成为世界第一位的 CO2 排放大国。尽管发展中国家当前不可能承担绝对的、强制性的减少 CO_2排放义务，但是随着发达国家减排承诺的履行，我国在未来国际谈判中也将会面临越来越大的压力。大力开发和利用可再生能源，是以技术创新应对气候变化的重要手段，也是我国制定和实施应对气候变化战略的重要措施。

1.3 开发和利用再生能源是解决农村基本用电和基本用能的重要途径

解决常规电网难以覆盖的边远农村地区的用电问题，是我国建设小康社会的一项目标。但目前无电人口仍有 700 万户，2900 万人。建立小型光伏发电系统和以小型风力发电为主的风-光、风-柴互补系统、微小水电、沼气工程等离网发电系统和户用发电系统，是解决边远农村地区供电的有效途径。我国目前已安装微小风力发展机 33MW，小型光伏发电系统 920kWp，微水电 174MW，解决了 57 万户农牧民用电问题。农村被动式太阳房、沼气池等成为解决农村生活用能的重要手段。农村户用沼气池已超过 1000 万个，年产沼气 37 亿立方米，已推广被动式太阳房 2660 万 m^2。并积极推广农村能源、环境、经济效益相结合农村可再生能源综合利用生态农业模式，将会更有力地促进农村地区的可持续发展。促进可再生能源在农村地区的开发利用，对边远农村地区发展经济、保护环境、实现小康目标有重要意义。

1.4 未来可再生能源领域的技术创新将在国家综合实力竞争中占据重要地位

可再生能源是未来可持续能源体系的重要支柱。据 UNDP 等国际机构预测，到本世界下半叶，可再生能源将逐渐取代传统化石能源而占据主导地位。可再生能源领域的技术创新能力，将成为国家综合竞争能力的重要方面，也将是国家经济、社会发展和国家安全的重要保障。当前，加强促进可再生能源发展的制度建设，具有显著的前瞻性和战略性意义。另一方面，减缓气候变化的核心手段是技术创新，大规模开发和利用可再生能源，减少 CO2 排放，是减缓气候变化的重要技术领域。这也将成为我国在能源领域推进技术创新的一个重要驱动力，也为我国实现跨越式发展，向可持续能源体系过渡提供了重要的历史机遇。

二、我国可再生能源发展的潜力

2.1　我国可再生能源资源的开发潜力巨大

我国国土面积广大，可再生能源资源品种多，分布广，数量丰富。太阳能年辐射量在3300兆焦/平方米•年到8400兆焦/平方米•年之间。其中2/3国土面积超过6000兆焦/平方米.年（200瓦/平方米），年日照数大于2000小时，相当于每年2.4万亿吨标准煤的储量。可以说只要技术可行、成本可接受，如此巨大的太阳能资源的开发利用量是没有上限的。我国陆地上离地面10米高度层上风能资源总储量约32.26亿千瓦，可开发利用的储量为2.53亿千瓦。近海可开发利用的储量有7.5亿千瓦，共计有10亿千瓦。我国拥有丰富的水能资源，其中技术可开发的小水电资源量为1.28亿千瓦，年生产电力0.45万亿千瓦时，占我国可开发的水电资源总量的29.7%，也居世界首位。生物质能资源也十分丰富，目前农作物秸秆年产量有7亿吨，可用作能源的约占50%，为3.5亿吨，薪材合理年开采量为2.2亿吨，各种工农业有机废弃物通过技术转换成沼气的资源潜力有310亿m3,而且，秸秆、薪材、各种废弃物资源都随着时间在不断增加。此外，通过我国大量低质土地种植能源作物，以及对自然生长的多种能源植物通过改造育种，在未来也将有几亿吨甚至更多的生物质资源潜力。

我国有几千公里的海岸线，有潮汐能，波浪能，温差能，盐差能等各种海洋能资源。据专家估计，可供开发利用量为0.5亿千瓦，其中在我国已能够开发利用的潮汐能为0.22亿千瓦。我国是以中低温为主的地热资源大国，其资源潜力占世界的7.9%。总盆地资源潜力在2000亿吨标准煤。其中可供开发的高温发电和中低温热利用的资源量分别为600万千瓦和33亿吨标准煤。

2.2 我国可再生能源的开发前景光明

要把可再生能源资源潜力变成实际的可利用量将主要取于各种可再生能源转换技术的发展、开发规模和政府扶持政策的推动。根据我国今后可再生能技术发展，市场环境的改善和政府政策支持，我国各种可再生能源开发前景将会十分光明。

（1）小水电是2020年前能大规模开发利用最现实的资源。2002年小水电装机已达2840万千瓦，到2020年其开发利用量可望达到8000万千瓦，占可开发量的63%，到2050年超过1亿千瓦，占可开发量的80%。

（2）风力发电已经具备跨跃式发展的条件，2002年装机已达40万千瓦，2020年国家发改委制订2000万千瓦的目标完全可以突破，而到2050可望实现3亿千瓦累计装机容量，占可开发量的30%。届时，风力发电将成为一种重要的可再生能源电力。

（3）太阳光电在2020年后将进入黄金发展时期。目前太阳光电的发展数量比起小水电和风电都要小得多，到2020年太阳光电装机容量为100万千瓦。但随着技术进步，规模发展，初始投资和发电成本大幅度下降，2020年后，将进

入高速发展阶段。2050 年，累计装机超过上亿千瓦的期望是可以实现的。除太阳光电，太阳能热利用也是重要的发展方向。太阳热水器、太阳房等技术都已成熟实用，进一步发展好太阳能建筑一体化技术，太阳能热利用有着更光明的前景。2002 年太阳能热水器已安装 4000 万平方米，居世界第一。2020 年和 2050 年太阳能热水器推广应用将分别达到 3 亿平方米和 20 亿平方米的目标并不是奢望。太阳能热利用总量分别相当于 3600 万吨标准煤和 2.4 亿吨标准煤。

（4）生物质能资源是最具潜力的可再生能源资源，它品种多，资源量可以不断增加，而且采用的技术多样化，除转换成电力外，还可以转化为热能或液态燃料使用。2002 年生物质发电装机已达 100 万千瓦，2020 年通过秸秆薪材高效直接燃烧，气化和沼气等发电技术，可以实现 2000 万千瓦的装机，同时，大力开发沼气燃料及生物柴油、生活酒精等非电利用，使生物质能利用总量达到 1.1 亿吨标准煤，而到 2050 年，实现 4 亿吨标准煤以上的期望是完全可能的。

（5）地热能和海洋能受技术发展和地理位置等因素影响，在 2050 年前将会适当地发展，但它们具有良好的发展远景。

三、可再生能源在我国能源体系中的战略地位

3.1 可再生能源将成为本世纪下半叶全球向可持续能源体系过渡的主要支柱

自上世纪 70 年代以来，由于“石油危机”引起发达国家对能源安全供应的关注，可再生能源技术的研发受到广泛重视，并且取了突破性进展。自上世纪 90 年代以来，发达国家减缓 CO_2 排放应对全球气候变化问题进一步成为发展可再生能源的巨大驱动力，使可再生能源大规模产业化有了迅速发展。可再生能源已成为欧盟等发达国家应对气候变化的核心技术手段，采取了强有力的促进和激动的措施，使可再生能源在近几年内大规模快速发展。德国和英国都通过立法宣布，到 2020 年可再生能源在一次能源总消费构成中将占 20%，欧盟则提出 2050 年可再生能源达 50%的发展目标。到本世纪下半叶时，可再生能源将逐渐取代化石能源而成为世界能源体系的支柱，从而呈现能源与社会经济的协调和可持续发展。

3.2 我国未来的经济、社会发展和能源需求情景分析

我国政府已制定了到 2020 年全面建设小康社会的奋斗目标，到 2020 年，GDP 比 2000 年翻两番，人均 GDP 达 3000 美元。

当前我国正处于工业化中初级阶段，重化工业发展速度，人民生活从温饱向小康过渡，因此对能源需求的增长趋势强劲。综合国内研究成果，2020 年我国在充分挖掘节能潜力，大力度推进节能措施，改进产业结构，优化能源结构的基础上，能源需求量仍将达 25~33 亿 tce。这对我国以煤为主的能源体系将产生巨

大压力，不仅环境污染将不可承受，而且能源资源的供应也不堪重负。石油对外依存度将超过 50%，对国家能源安全也带来巨大的威胁。表 3.1 给出我国未来经济发展与能源消费的一种情景分析。未来可再生能源的开发利用也势必成为国家向可持续能源体系过渡的主要途径。

到 2050 年，我国人均 GDP 按 2000 年的不变价超过 10,000 美元，基本实现现代化。届时能源消费将达 50 亿 tce 左右，从 2020 年到 2050 年，能源消费弹性约为 0.35，与目前发达国家的水平相当，我国将以较低的能源消耗实现工业代和现代化的发展目标。

表 3.1　未来中国经济、能源与碳排放参考情景

	2000	2020	2050
人口	12.62	14.27	15.61
GDP（10^9美元，2000 价）	1079.7	4319	17628
人均 GDP（美元/人，2000 年价）	856	3027	11290
一次能源消费（Mtce）	1303	3000	5000
GDP 能源强度（kgce/美元）	1.21	0.69	0.28
GDP 年增长率（%）		7.2	4.8
能源消费弹性		0.59	0.35
GDP 能源强度下降率（%）		2.8	3.0

3.3 可再生能源在未来能源体系中的重要作用

根据未来发展目标及对可再能源技术的评价，对未来能源体系构成的情景分析列入表 3.2。在情景分析中，未来可再生能源的发展规模大都比 2.2 节中可再生能源开发前景评价中的数据留有余地。表中水能、风能、太阳能和其它可再生能源发电，均按届时发电平均能耗折合为一次能源当量进行计算。

到 2020 年，不包含大水电在内的可再生能源可占一次能源总量的 8.6%（含大水电为 15.4%），在能源供应中已开始发挥积极作用。到 2050 年，可再生能源的比重可上升为 21.6%（包含大水电可达 27.5%）。煤炭到 2020 年在一次能源中的构成下降到 53.7%，到 2050 年煤炭在一次能源中的构成将下降到 40%以下，从根本上改变了以煤炭为主的一次能源格局。石油到 2020 年需求量约 4.5 亿吨，原油产量为 1.8~2.0 亿吨，进口量将超过 2.5 亿吨，进口依存度约 60%，其后新增液态燃料的需求，将主要由煤炭液化和生物质液态燃料满足，或由天然气、燃料电池等替代，石油消费量争取不再大幅上升。天然气发展尚处于青年期，年产量将持续增加，到 2020 年可望达到 1000 亿 m^3，但需求量可达到 1600~2000 亿 m^3，尚需较大规模进口。从 2020 年到 2050 年，维持 3%左右年增长率是可能的。到 2020 年，核能装机达 3600 万千瓦，2050 年达到 2 亿千瓦是可能的，其余能源供应则依靠可再生能源满足。从 2020 年到 2050 年按 GDP 再翻两番，年增长速

表 3.2 未来能源消费构成的情景分析

	2020 年		2050 年	
	Mtce	%	Mtce	%
煤炭	1611	53.7	1970	39.4
石油	643	21.4	720	14.4
天然气	213	7.1	546	10.9
核能	71	2.3	388	7.8
水能	300	10.0	416	8.3
其中小水电	96	3.2	120	2.4
风能	16	0.5	205	4.1
生物质能	110	3.6	400	8.0
太阳能	36	1.2	320	6.4
其他可再生能源			35	0.7
合计	3,000	100.0	5,000	100.0

度为 4.8%计，到 2050 年我国人均 GDP 按 2000 年价将超过 10000 美元，届时能源消费将达到 50 亿 tce 左右。届时可再生能源在我国能源体系中将发挥至关重要的作用。2050 年以后，随着经济和社会发展所新增长的能源需求，可主要依靠发展可再生能源满足，从而向可持续能源体系过渡。

到 2020 年，发电装机容量将近 10 亿千瓦，包含大水在内的可再生能源装机比重达 31.8%，发电用能在一次能源中的比重达 49%。到 2050 年，发电装机容量将超过 20 亿千瓦，在一次能源中的比量可达 52%。在电力装机中，可再生能源将占 32.4%，包含大水电在内，其比重将达 43.1%，见表 3.3

表 3.3 未来电力装机构成情景分析

	2020		2050	
	GW	%	GW	%
煤电	563	59.2	800	38.6
天然气发电	60	6.3	180	8.7
核电	36	3.8	200	9.7
水电	250	23.6	320	15.5
其中小水电	80	8.4	100	4.8
风电	20	2.1	250	12.1
生物质发电	20	2.1	200	9.7
太阳光电	1.0	0.1	100	4.8
其他可再生能源发电			20.0	1.0
总计	951	100.0	2070	100.0

可再生能源在我国能源体系中将发挥越来越重要的作用，是我国长远解决能源资源紧缺和环境污染两大问题的根本出路，也是我国未来建立可持续能源体系

的重要支柱。我国必须制定长远发展战略，克服当前机制上和市场的障碍，制定有效的激励政策，促进可再生能源的大规模产业化发展。

四、可再生能源发展的战略思路和目标

4.1 可再生能源发展的战略思路

可再生能源发展的战略思路可概括为：坚持“目标引导、国家扶植、市场推动、技术创新、企业竞争、公众参与”的方针，以国家可再生能源发展战略目标为引导，以法律、法规、财税等经济激励政策为保障，以当前解决日益严重和紧迫的资源瓶颈性约束和环境污染问题和长远解决国家能源可持续供应、保障国家能源安全以及减缓气候变化问题为驱动力，以加强技术创新、掌握关键技术、降低成本、建立完善的市场机制、推进可再生能源技术产业化和提高企业竞争能力为核心，以提高可再生能源电力在电网中的份额为重点，实现可再生能源技术和产业化的跨越式发展。同时对解决边远农村地区的能源、电力供应以及能源、环境、经济的协调发展发挥重要作用。

促进可再生能源的发展，关键要把握好国家、各级政府主管部门、企业和社会公众各自的定位，建立起促进可再生能源产业健康发展的市场机制，使可再生能源企业在市场竞争中不断创新，发展壮大。

4.2 可再生能源发展的战略目标

为与能源领域中长期规划相协调，可再生能源发展的战略目标选择为 2020 年和 2050 年，分别提出其发展目标。

2020 年的战略目标是：加快小水电的发展速度，发电装机容量达 7000～8000 万千瓦；加快风电、生物质发电的产业化步伐，风电装机达 2000～3000 万千瓦，生物质能发电装机 1000～2000 万千瓦；加强对太阳能光伏发电研发和示范工程的支持力度，光伏发电超过 100 万千瓦；可再生能源发电总装机容量比 2000 年翻两番，超过 1.2 亿千瓦。加强推进太阳能热利用和建筑一体化，太阳能热器水面积达 2.5～3.0 亿 m^2，生物质液态燃料年产量达 1500 万吨。初步建立可再生能源的产业体系和市场机制，可再生能源在能源构成中占 10%以上，同时以可再生能源为主体，解决农村无电地区的电力和能源供应问题。

2050 年的战略目标是：可再生能源技术达世界先进水平，形成完善的可再生能源产业体系和市场机制，形成小水电、风电、生物质能发电、太阳能光伏发电以及太阳能热利用和生物质燃料等其它可再生能源利用形式因地制宜、竞相发展、多种能源形式互补的协调发展态势，包含大水电在内的可再生能源在一次能源中的比重接近 30%，可再生能源电力占总电量的比重超过 1/3，为本世纪下半叶向以可再生能源为主体的可持续能源体系过渡打下坚实的基础。

4.3 可再生能源技术研发的重点领域

根据可再生能源发展的战略思路和目标，对可再生能源技术研发的重点领域归纳如下。

（1）风力发电技术，重点是兆瓦级大容量及变桨距、变转速新型风电机组和海上风电场技术。

（2）太阳能利用技术，重点研发先进光热转换材料、集热器结构部件、新型光伏电池材料和组件技术、并网和屋顶光伏发电系统以及建筑一体化技术等。

（3）生物质发电和燃料化技术。重点是生物质热解气化及发电技术，沼气生产及发电技术，纤维素类原料生物质酒精、生物质酶法合成生物柴油、生物质制氢以及城市垃圾综合利用技术。

（4）其它可再生能源技术，包括太阳能制氢、新一代地热综合利用技术、海洋能独立发电和综合利用技术，可再生能源综合利用和互补系统等。

五、促进可再生能源发展的政策与措施

5.1 明确可再生能源在我国能源战略中的长远重要地位，加强促进可再生能源发展的综合制度建设

可再生能源快速、健康地发展，需要国家综合制度的建设，要形成国家立法、政策激励、公众参与的市场机制，促进可再生能源产业技术创新和大规模占领市场。当前要充分认识可再生能源对我国长远建立可持续能源体系的重要战略地位，加大对可再生能源发展的扶植力度，为可再生能源产业的发展创造良好的市场环境。鼓励可再生能源企业的竞争与创新，广泛吸纳社会资金和人才，使之成为新的投资热点和新的经济增长点。国家能源主管部门要加强协调和系统规划，逐渐形成和完善促进可再生能源健康发展的制度和机制。

5.2 建立和完善可再生能源发展的市场机制，激励创新，提高企业竞争力，加快可再生能源产业化发展

企业是实施技术创新的主体，可再生能源的产业化发展，关键在于提升可再生能源企业的技术创新能力和市场的竞争能力，建立能够促进其健康发展的市场环境和市场机制。发达国家的成功实践表明，通过国家立法，实行强制性的可再生能源市场规则，对促进可再生能源产业化发展有至关重要作用。发达国家普遍推行的促进可再生能源发展的机制有配额制、购电法（或保护性电价制度）、竞争性招投标制度（或特许经营权制度）。根据我国实际情况，当前以实施保护性电价制度较为适宜，在酝酿中的《可再生能源促进法》中，也拟采取该种机制，并与国家可再生能源的发展目标相结合，以价格和数量两个方面的规定，保障可再生能源促进机制的形成。

5.3 加强政府扶植力度和调控能力，为可再生能源产业的发展提供良好的政策环境和发展舞台

我国对可再生能源的发展一直采取积极支持和扶植的态度，已有若干个行政法规和地方性法规。这些政策措施对于再生能源的发展起了重要推动作用。但还没有形成系统的和配套的综合性政策体系，支持和扶植的力度也有欠缺，资金的来源和渠道也没有根本保障。国家应建立支持可再生能源的财政专项资金（或公共利益基金 PBF），列入国家经常性财政预算项目之中，并建立专门的政策性融资体制，以支持可再生能源技术研发和产业化发展。同时政府主管部门要加大调控力度，加强对可再生能源市场以规范和监督，调控好价差分摊和各方面的利益，为可再生能源产业发展提供良好的市场环境。

5.4　建立和健全可再生能源产业化的技术支撑体系和服务体系，保障可再生能源产业的健康发展

在当前可再生能源技术迅速发展的形势下，需要建立完善的技术支撑和服务体系，规范和促进其健康发展。因此，要制定各项可再生能源技术和产品的国家标准和行业标准；支持建设风能、太阳能、物质能等可再生能源设备和产品的检测机构，积极开展可再生能源设备和产品的检测；建立风能、太阳能、生物质能等可再生能源设备和产品的认证体系，实施可再生能源电力认证制度；积极培育可再生能源技术服务市场，支持可再生能源专业性服务企业的发展，对可再生能源技术的推广和服务提供支持。

5.5 强化政府职责和电网企业普遍服务义务，促进可再生能源在农村地区的开发利用

各级地方政府负有保障农村地区基本用电和基本用能的义务，需要用财政手段和强制性政策为农村地区供电和供能。开发利用可再生能源是解决边远农村地区用电和用能的重要途径，特别是可再生能源离网发电和户用发电系统是解决无电人口基本用电的主要手段。政府在加大资金和政策支持力度的同时，要强化电网企业的社会普遍服务的义务。电网企业应当充分利用小型风力发电系统、小型光伏发电系统、风光互补发电系统、微（小）型水力发电系统等可再生能源技术离网发电系统和可再生能源户用发电系统，解决无电人口的基本用电和基本用能，政府在投资和费用上给予补贴。同时要积极支持和推广能源开发、环境保护和经济效益相结合以农村地区可再生能源的综合利用模式，使可再生能源的开发利用成为解决“三农”问题的重要手段。

5.6　加强可再生能源领域的研发和技术创新，并作为优先领域纳入国家中长期科技规划

可再生能源技术是我国战略必争的高技术领域，是国家建立可持续能源体系

的核心技术，也是反映国家综合科技实力和国家综合竞争力的一项重要标志。我国应坚持自主研发与技术引进相结合的方针，掌握核心竞争力技术，实现产业化。当前要把大规模开发利用可再生能源关键技术作为优先领域，纳入国家中长期科技发展规划，加大研发投入，给予重点支持。在可再生能源技术研究和产业化过程中，应处理好核心技术的长远攻关目标与近期产业化项目的关系，处理好成套引进与自主研发的关系，处理好主流技术路线与创新性技术路线的关系，处理好研发项目竞争立项与科研能力平台建设的关系，形成并完善国家能源领域的科技创新体系。

5.7　加强可再生能源信息传播和公众意识的培养，吸引社会对可再生能源开发利用的广泛参与

国外实践表明，公众的广泛参与和舆论的导向对可再生能源的发展有至关重要的影响。通过信息传播、教育、培训和科技普及等手段，提高和增强公众开发利用可再生能源的意识，促使公众和企业自觉认购可再生能源电力和使用可再生能源产品，参与可再生能源的开发和利用，吸引社会对可再生能源产业投资，兴办可再生能源生产企业和服务性企业，促进可再生能源的发展，同时使政府和企业在可再生能源开发利用的规划和义务方面受到公众和舆论的监督，形成促进可再生能源发展的健全机制。

5.8 加强国际合作，促进先进可再生能源技术向国内转移

当前世界范围内可再生能源迅速发展的形势，有利于开展国际合作。发达国家也十分关注中国的广阔市场。在国内加强对可再生能源技术研发和产业化力度的同时，要加强研发领域的国际合作和成套技术的引进，积极参加双边、多边的国际合作计划，特别是应积极参与在《气候变化公约》框架下的技术转让和国际合作，引进资金和技术，促进我国可再生能源技术和产业的发展。同时积极支持国内企业和研究机构向国外出口可再生能源技术和产品，提高我国可再生能源领域的国际竞争力。

中国小水电技术现状与展望

刘京和（水利部）

2005.10

一、水能资源状况

1.1 我国的水能资源

构成河流水能资源的两大要素是径流和落差，中国具有径流丰沛和落差巨大的优越自然条件。中国境内所有流域面积在 100km^2 以上的河流共 5000 余条。其中，河长在 1000km 以上者有 20 条；流域面积在 1000km^2 以上者有 1600 余条；水能资源蕴藏量在 10MW 以上者有 3019 条。

中国河流水能资源蕴藏量 676GW，年发电量 5920TWh；可能开发水能资源的装机容量 378GW，年发电量 1920TWh。不论是水能资源蕴藏量，还是可能开发的水能资源，中国在世界各国中均居第一位。

我国国土面积与巴西、俄罗斯、加拿大和美国相当，年径流总量均小于这些国家，但水能蕴藏量却超过这些国家而位居世界之首，主要得益于我国大陆东西部之间高落差的阶梯状地理特征。从“世界第三极”青藏高原到海拔仅 50m 的沿海平原之间存在着高达 4000m 以上的大面积落差，这是世界绝无仅有的。

至 2004 年 10 月我国的水电装机已突破 100GW。占可开发水能资源的装机容量的 26％。

表 1：中国水能资源

水系	水能资源蕴藏量			可开发的水能资源		
	MW	GW.h/a	占全国 (%)	装机容量 (MW)	年发电量 (GW·h/a)	占全国 (%)
全国	676047.1	5922180	100	378532.4	1923304	100
长江	268017.7	2347840	39.6	197243.3	1027498	53.4
黄河	40548.0	355200	6.0	28003.9	116991	6.1
珠江	33483.7	293320	5.0	24850.2	112478	5.8
海滦河	2944.0	25790	0.4	2134.8	5168	0.3
淮河	1446.0	12700	0.2	660.1	1894	0.1
东北诸河	15306.0	134080	2.3	13707.5	43942	2.3
东南沿海诸河	20667.8	181050	3.1	13896.8	54741	2.9

西南国际诸河	96901.5	848860	14.3	37684.1	209868	10.9
雅鲁藏布江及西藏其他河流	159743.3	1399350	23.6	50382.3	296858	15.4
北方内陆及新疆诸河	36985.5	323990	5.5	9969.4	53866	2.8

图 1　　中国水能资源分布

1.2 我国小水电资源的特点

在我国小水电被定义为装机容量不超过 50 MW(含 50 MW)的小型及微型水电站。中小支流遍布全国，小水电资源十分丰富。据初步普查资料统计，小水电资源的蕴藏量为 160GW。相应的年电能约为 1300TWh；5 万 kW（含 5 万 kW）以下的小水电资源可开发量达到 1.28 亿 kW。至 2004 年我国已开发小水电装机容量为 3865 万 kW，已开发的小水电资源占可开发资源的 32％，已开发的小水电占整个水电装机的约 40％，小水电发展潜力也是很大的。

我国小水电资源广泛分布在全国 1600 多个山区县，主要集中在中西部地区，其中西部地区小水电技术可开发量占全国的 63.6%；中部地区小水电可开发量占全国的 17.8%。东部地区小水电可开发量为 18.5%。我国西部小水电资源目前仅开发了 900 多万 kW，占可开发水电资源的 12.1%。开发水平偏低，存在着极大的发展空间。我国小水电资源剩余技术可开发量及分布见图 2。

表 2：中国可开发中小水力资源分布情况 单位:MW

省份	小水电	中型水电	总计	省份	小水电	中型水电	总计
北京(BJ)	90.0	448.5	538.5	湖北(HB)	4036.0	1592.2	5627.1
河北(HE)	939.3	346.0	1554.7	湖南(HB)	4146.0	2798.2	6944.2
山西(SX)	581.0	346.0	927.0	广东(GD)	4166.0	2313.2	6479.2
内蒙(NM)	387.0	1196.0	1583.0	广西(GX)	2322.0	2589.0	4911.0
辽宁(LN)	429.1	1028.9	1453.0	海南(HI)	397.0	286.3	683.7
吉林(JL)	1887.9	1423.1	3311.0	四川(SC)	5878.0	12786.3	18664.3
黑龙江(HL)	728.0	777.8	1505.8	贵州(GZ)	2554.0	3640.5	6194.5
江苏(JS)	112.0		112.0	云南(YN)	10250.0	7175.8	17425.8
浙江(ZJ)	3226.5	1172.5	4399.0	西藏(XZ)	16000.0	2348.0	18348.0
安徽(AH)	684.5	450.5	1135	陕西(SN)	1569.0	1553.5	3102.0
福建(FJ)	3594.0	2724.9	6318.9	甘肃(GS)	1089.0	2547.6	3636.6
江西(JX)	3083.3	2308.9	5332.2	青海(QH)	2000.0	3214.6	5214.6
山东(SD)	215.0		215.0	宁夏(NX)	23.0	55.0	78.0
河南(HN)	1031.0	522.5	1553.5	新疆(XJ)	3979.0	7287.7	11226.7
				总计	71870.0	63181.3	150513

我国小水电资源开发量位居前 6 位的省区是广东、四川、福建、云南、湖南、浙江，开发量分别为 408 万 kW、367 万 kW、362 万 kW、233 万 kW、217 万 kW 和 206 万 kW。2002 年开发率居前 4 位的省区是广东、福建、浙江和海南，开发率分别为 64%、52%、47%和 47%。

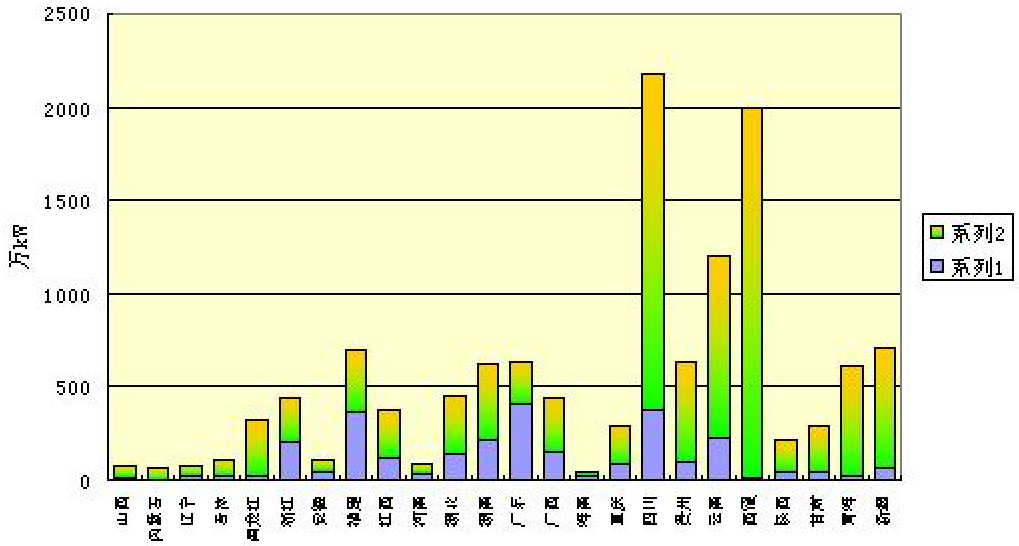

图 2　　我国小水电资源潜力及已开发情况

二、技术发展状况

2.1 我国小水电技术及产业发展现状

小水电技术主要包括流域规划技术，水工建筑物设计施工技术，小型水轮发电机组设备制造技术，水电站计算机监控技术，电网自动化调度技术及输配电计算机监控技术等。

流域规划技术主要包括小流域梯级开发、龙头水库开发、高水头电站跨流域开发等，通过把流域作为一个有机的整体，进行系统研究，找出符合整个流域最大水力资源利用率、最大发电效益、最大社会效益和环境效益的开发方案。目前，小水电流域规划技术发展迅速，并逐步推广应用到全国小水电开发中。

小水电的水工建筑物技术主要包括⑴砼重力坝、砌石拱坝、小型砌石连拱支墩坝、砼拱坝、橡胶坝、砼面板堆石坝、土坝等挡水建筑物技术；⑵发电引水、跨流域引水和虹吸式进水等引水建筑物技术。小水电水工建筑物投资比例大，工程进度也受其制约，因此，水工建筑物技术发展可以有效减少工程投资、加快施工进度。

砌石拱坝，特别是较低坝高（小于 50m）的水电工程，是目前我国小水电工程挡水建筑物中用得较多的一种坝型。与同等规模的砌石重力坝相比，可节省工程量的 1/2～1/3。砌石连拱支墩坝主要有拱形盖板和支墩组成，当河谷宽度较宽，坝高不大，河床及坝两岸基础条件较好时常采用此坝型。使用浆砌石连拱坝可较同等规模的浆砌石重力坝节省工程量 30～50%。

虹吸式进水口在小水电工程中被广泛应用。虹吸式进水口可以快速切断水

流，提高运行可靠性，降低运行费用，并节约 20%～30%的土建投资。我国现有虹吸式进水口设计水头已达 127m，最大引水流量 $14m^3/s$，单机容量为 3MW。我国小水电工程中很多采用了钢筋混凝土预应力管道，其加工已经工厂成品化和系列化，用预应力钢筋管代替压力钢管可节省投资 30%以上。

我国颁布了 50 MW 以下水轮机的行业标准。在低水头电站中大力推广灯泡贯流式机组,采用此种机型替代轴伸贯流式及轴流式，使机组尺寸小、重量轻、效率高及厂房小，电站投资大幅下降。大力开发整装灯泡贯流式机组、立式轴流式及混流式及冲击式水轮发电机组。机组的组装、试验在工厂内完成，整体运输和吊装，即保证了产品的质量，又节约了机组安装周期。在卧式机组设计中推广 2 支点结构新技术，使机组维护环节减少，安装调整时间缩短，有效降低了设备及厂房造价。调速器系统及励磁装置等辅助设备，科技含量和产品质量已接近国际先进水平。

目前，小水电设备技术水平已有显著提高，主要表现为：水电设备开始由常规设备向微机型设备转型，自动控制系统进入计算机数字控制阶段。经济较发达地区已采用了先进的调度自动化系统和变电站综合自动化系统，部分水电站和变电站实现了无人值班。技术改造和节能技术在各地也普遍得到推广应用，一些小水电站通过采用置换高效转轮、新型励磁装置等新技术和新装备，设备效率大幅提高，取得了可观的经济效益。

我国水电站优化运行及流域梯级优化调度发展很快。梯级电站的梯调计算机监控系统采用分层分布式结构，和水情测报系统接口，能对水库上游降雨量、水库水位等水文信息的自动接收，从而实现流域梯级电站优化调度。

小水电配套电网网络结构趋于合理，布局更可靠，运行更灵活，供电能力和质量有了显著提高，低压线损率普遍从改造前的 25%降低到 12%左右。自《农村水电电力系统调度自动化规范》（SL/T53）发布以来，农村电网调度自动化的水平逐步提高。目前，各地已部分实现了地区调度自动化或县级调度自动化，功能达到 SCADA 技术要求，并且符合实用化标准。同时我国大力推广变电站自动化，目前农村 35kV、110kV 变电站积极采用微机综合自动化系统，部分已实现无人值班或少人值守

在总结工程经验和科技成果的基础上，水利部发布了涉及小水电规划、设计、施工、质量、管理、试验、设备等各个环节的行业技术标准，形成了具有中国技术特色的小水电技术标准体系。

我国已建立起由科研机构、院校和企业组成的包括研究、试制、生产在内的完整的小水电技术装备产业体系。全国有水科院、水利部杭州农电所、天津电气传动研究所、清华大学、中国农业大学、华中科技大学等三十余家科研院所从事

小水电技术装备的研发；有 160 多家小水电设备制造厂家，其中较大规模的企业有东风电机厂、重庆水轮机厂及富春江富士水电设备有限公司等二十余家，以制造单机容量 5 万 kW 以下的混流式、轴流式、冲击式和贯流式水轮发电机组为主。中小规模的企业有杭州发电设备厂、兰州电机厂及金华水轮机厂等百余家，以制造单机容量 1 万 kW 以下的水轮机发电机及辅助设备为主。小水电设备制造厂家年生产能力超过 2,000 MW。在过去的 40 年期间，生产了 24 万余套小型、微型水轮发电机组，其中 500 kW 以上容量的水轮发电机组超过 5 千台。国产化的水电设备基本能够满足现阶段我国小水电发展的需要。

三、小水电行业发展目标及技术发展展望

我国的小水电开发主要是服务于地方经济建设，尤其是广大农村地区。小水电开发的一个重要特点是与农村经济发展和实现农村电气化密切结合起来，近 20 年来，国家以水电农村电气化形式组织小水电开发。随着我国农业结构升级、农村经济壮大和农民致富步伐的加快，目前小水电已进入到一个新的发展时期，小水电也成为满足农村电力需求、解决无电人口、扶贫、保护生态、替代常规电力等多目标的系统。

3.1 小水电发展方针

⑴ 满足农村电力需求与解决无电人口问题

从上世纪五十年代至今，满足农村电力需求与解决农村地区无电问题始终是小水电的主要目之一。地方政府依靠社会集资、群众投工投劳，因地制宜开发水电资源，为边远地区区域经济发展提供了电力。半个世纪来，小水电经历了从早期以解决无电问题为主到现阶段以提高用电水平为主的过程，共解决了 3 多人口用电问题，并为占国土面积 1/2 的区域提供了基本电力的公共服务。

目前我国农村边远地区用电水平仍然偏低，特别是在电网末端和离网的分散供电地区，人均用电量不到全国农村人均用电量的 1/4；全国尚有 1000 多万无电人口，这些人口所在地区地理位置极为偏远，负荷少而分散，用电网延伸来解决供电问题是不现实的。因此，通过农村电气化提高用电水平和最终解决无电人口问题仍是小水电今后相当长一个时期的主要目标。

⑵ 提高农村贫困人口收入

有关资料表明，大部分贫困人口集中在我国地势第一、二级阶梯的过渡带上。这些地区的地貌特征是山地、丘林和高原，其中大部分是山地。这些地区又属于季风气候边缘地带，气候变化剧烈，水土流失严重，自然生态环境脆弱。

偏远贫困山区的经济选择性十分有限，产业结构仍以传统落后农业为主。由于可耕地少，土壤贫瘠，农作物产量低，没有足够的剩余农产品用来增加收入，

很多家庭的收入低于国家贫困线。偏远山区的贫困人口，要么没有用上电，要么只能获取十分有限的电量。主要依靠生物燃料、人力或牲畜来满足生活生产用能需求。缺乏电力基础设施是制约偏远山区产业发展与结构升级的瓶颈，也是当地居民难以摆脱贫困的主要原因之一。

开发小水电能够有效促进贫困地区乡镇企业和家庭作坊的发展，增加农村就业机会，提高农民收入。尤其是容量 100kW 左右的乡村级小水电供电系统，不仅能满足分散的贫困家庭生活用电需求，而且能为生产提供基本电力，对消除贫困有着十分积极的作用。

⑶ 保护生态环境

小水电属于清洁可再生能源，具有治理环境，保护生态的重要作用。小水电工程治水办电相结合，通过在江河源头建设一大批综合利用的水利水电枢纽工程，采用生物、工程治理等多种手段，提高植被覆盖率，涵养水源，防止水土流失，对小流域进行综合治理。不仅能够改善当地的生态环境，还能逐步从根本上保护和修复江河中下游的生态环境；小水电提供的电力减少了农民对生物燃料的依赖，使大量林木免被砍伐。特别是在退耕还林还草区、天然林保护区、自然保护区和重点水土流失区，实施小水电代燃料生态保护工程有着十分重要的作用。

⑷ 替代常规电力

随着我国经济总量快速扩张，能源的生产与消费规模也相应迅速增长，工业化进程中引发的污染对生态环境造成的损害越来越突出，成为我国社会经济发展的重要制约因素。由于化石燃料储量的有限性、不可再生性以及高昂的环境成本，我国以煤、石油、天然气为主的能源供应结构潜在着危机。为了实现可持续发展，目前国家已开始考虑加大可再生能源产业规模以替代常规能源。我国小水电资源储量非常丰富，分布广泛，使其成为能够有效替代常规电力的主要清洁可再生能源之一。这些水能资源如果得到充分开发，小水电装机容量将占 2020 年全国电力总装机的 12%，每年可产生 0.64 万亿 kW.h 替换电量，节省近 2 亿 t 煤炭。

3.2 小水电发展目标

（1） 2020 年农村电力需求与供应预测

党的十六大明确提出了“全面建设小康社会，在优化结构和提高效益的基础上，国内生产总值到 2020 年力争比 2000 年翻两番”，并且提出“到 2020 年基本上实现工业化”的奋斗目标。届时我国农村社会经济、能源供应结构、农村居民用能方式、电力消费总量也将发生巨大变化。

预计 2020 年随着农业生产方式的现代化及农村居民平均可支配收入的提高，农村居民用能方式将发生较大变化，生物质能直接燃烧利用不断减少，电力及油气等优质商品能源稳步增加。用能结构和方式逐步与城镇趋同，用能数量达

到目前国内经济较发达地区城镇居民平均消费水平。

预计 2020 年全国农业用电量占全国用电量的 3.7%。从现在到 2020 年我国农村居民人均生活用电量平均每年以 10.6%的速度增长，届时达到人均 600 kW·h。2020 年全国农村用电总量为 590000TW·h，占全国用电量的 13.4%。占农村终端能源消费总量的 12.6%。

据统计，自上世纪 90 年代末至本世纪初，我国小水电装机规模平均每年以 6.46% 的速度增长（见表 2）。以此增长速度推算，2010 年我国小水电装机规模将达到 46990 MW,占技术可开发总量的 37%;2020 年小水电装机规模将达到 87710 MW，占技术可开发总量的 68.5 %。要保持这一年均增长速度，平均每年需新增电力装机 3320 MW。

在得到国家可再生能源法律支持及小水电在 2015 年前顺利实现现代化的条件下，小水电有可能实现开发率达到 70%，甚至更高的目标。届时小水电年发电量为 448000TW.h，占 2020 年全国农村用电量的 76%左右。

2020 年小水电仍然是我国近 1/2 的地域、1/3 的县和 1/4 的人口的主要电力供应者。小水电将不断提高这些地区农业与居民生活用电水平，并担当起向当地不断崛起的小城镇提供基本电力供应的任务。

（2） 我国小水电技术发展路线

我国小水电技术发展的指导思想是：以“科学技术是第一生产力”的思想为指导，坚持为农业、农村、农民服务的方向，以满足农村经济社会发展对农村水电的需求为目标，以现代技术和现代管理为手段，以小水电厂及配套电网自动化、信息化技术为重点，不断提高小水电行业的技术水平及运行管理水平，保证发、供电质量，提高发、供电的安全性、可靠性、经济性，增强小水电的经济实力和市场竞争能力，为小水电事业持续快速健康发展提供技术保障。

技术发展所遵循的原则是：明确目标，统一规划，加快实施，适当超前；技术先进，设备可靠，简单方便，经济合理；严格执行国家技术标准，优先选用系列化产品；以国产技术和设备为主，适时引进国外关键技术和设备。

小水电技术进行的开发将集中在新材料上，如合成材料。

对于低水头，开发则集中在多样布置的小机组上，采用变速和变频技术。

“变压发电”（powerformer）发电机，在将来可适用小水电站

对于一些水电站，已经尝试对主要部件或甚至整个电站进行预制，采用箱式整装小水电，估计该产品在产量上和规模上会得到发展，产品的系列会更齐。

水电站设计中环境和安全问题摆在了一个比较重要的位置。

降低工程造价与减少运行费，提高资源利用率的各种技术开发。

技术发展总体目标是：2010 年前，50%的小水电站及配套电网达到现代化水

平。2015 年，小水电行业全面实现现代化。通过科技创新，管理创新，使小水电市场竞争力明显提高。

四、制约技术发展的主要障碍与对策建议

4.1 小水电自身方面

⑴ 电力生产规模小。可再生能源在商业化运作中面临的主要共性问题是：可再生能源市场相对狭小，小规模的生产造成较高的工程设备投资成本，低产量的能源生产又会造成较高的能源生产成本。小水电同样存在这一问题。实际上即使在发达国家，小水电与常规能源目前仍无法进行完全的市场竞争，其发电成本因经济规模的限制与常规能源仍有一定的距离。

⑵ 丰枯及峰谷矛盾。小水电大部分是径流式电站，缺乏调节能力，在丰水期往往造成系统电力有余，小水电大量弃水；而枯水期造成电网缺电。受负荷特性限制，在负荷高峰期，不能提供更多的电力；在负荷低谷期，又会因电网负荷小而停机弃水。

⑶ 气候变化。小水电设计发电量是按水文、水能条件得出的平均多年发电量，这些水文资料大多来源 80 年代以前，由于近年来气候变暖，径流年际与年内变化加剧，导致与原来设计差距较大，在一定程度上影响了发电量。

⑷ 机组技术水平及效率低。小水电站由于建站时间长，大部分设备陈旧、技术落后、能量转换效率偏低。据统计，单机容量在 500~3000kW 段机组，其综合效率低于 80%的占 54%；单机容量在 3000~12000kW 段机组，其综合效率低于 80%的占 38%。

⑸ 运行方式不当。相当多的水库电站缺乏对水文资料、发电单位耗水率、水头与运行台数的相关分析，运行方式粗放。不能优化水库调度和电站运行计划，在提高水库防洪安全度的同时，增加发电量。径流式电站也存在运行方式不当的问题。

⑹ 机组检修及事故停机等。除机组正常检修外，设备老化使事故停机增多，延长了检修时间，减少了发电量。

发电量减少使小水电实际的单位电能造价和发电成本大幅度提高，发供电收益普遍达不到项目财务评价预期值，消弱了市场竞争力。2002 年全国小水电平均实际发电成本比平均设计发电成本高出 0.06 元/kW.h。在 64 座小水电站经济性抽样调查案例中，以平均上网电价为 0.25 元/kW.h 计，平均实际发电成本比平均电价高出 0.05 元/kW.h。

4.2 小水电体制、市场及政策方面

虽然我国小水电技术进步使其商业化运作能力不断加强，但与我国电力工业

发展整体水平相比还存在一定差距，主要表现在小水电总体技术水平不高，技术市场发展缓慢，科技成果转换渠道不畅及科研经费投入不足等方面。其他还包括：

⑴ 小水电资源管理体制不顺、职责不清。由此给小水电的资源、规划及开发管理带来诸多问题，造成资源配置的低效率。

⑵ 电力输出困难。由于国家电力体制存在垄断性及电力市场发育不成熟，在国家电网和小水电的所属关系不同的情况下，电网对其上网采取丰水期限发等种种限制措施，长期以来小水电发电上网问题不能很好解决。

⑶ 电价定价机制不合理。小水电电价形成缺少规范化的政策法规。现行电价水平既背离价值规律，又不能反映市场供求关系。不利于通过市场配置资源，严重影响了小水电企业的生存、巩固和发展。

⑷ 公益性制约。部分小水电站是依附于水利工程而建，除了发电，还兼有防洪、灌溉、供水等综合功能。水电站运行必须首先服从于防洪及工农业用水的需要，造成蓄水期减发或不发，放空迎汛时弃水减发，灌溉供水期不惜超低水位运行或能发峰电发了谷电等。

⑸ 扶持政策十分有限。小水电现行政策是以基于计划经济的激励政策为主，市场机制的作用基本没有体现出来。为了纠正“市场扭曲”和“政策扭曲”，目前急待出台具有市场机制的新政策

如果所有以上这些来自体制、市场、政策及自身的障碍得到解决，小水电实际年发电量比设计年发电量估计能多 30%左右，部分电站可高达 50%以上。

中国风电发展未来展望

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一、风能资源

1.1 风能储量

我国幅员辽阔，海岸线长，风能资源比较丰富。根据全国 900 多个气象站陆地上离地 10m 高度资料进行估算，全国平均风功率密度为 100W/m2，风能资源总储量约 32.26 亿 kW，可开发和利用的陆地上风能储量有 2.53 亿 kW，近海可开发和利用的风能储量有 7.5 亿 kW，共计约 10 亿 kW。如果陆上风电年上网电量按等效满负荷 2000 小时计，每年可提供 5000 亿千瓦时电量，海上风电年上网电量按等效满负荷 2500 小时计，每年可提供 1.8 万亿千瓦时电量，合计 2.3 万亿千瓦时电量。

1.2 风能资源分布

我国面积广大，地形条件复杂，风能资源状况及分布特点随地形、地理位置不同而有所不同。风能资源丰富的地区主要分布在东南沿海及附近岛屿以及北部地区。另外，内陆也有个别风能丰富点，海上风能资源也非常丰富。

北部（东北、华北、西北）地区风能丰富带。北部（东北、华北、西北）地区风能丰富带包括东北三省、河北、内蒙古、甘肃、青海、西藏和新疆等省/自治区近 200km 宽的地带。三北地区风能资源丰富，风电场地形平坦，交通方便，没有破坏性风速，是我国连成一片的最大风能资源区，有利于大规模的开发风电场，但是当地电网容量较小，限制了风电的规模，而且距离负荷中心远，需要长距离输电。

沿海及其岛屿地区风能丰富带。沿海及其岛屿地区包括山东、江苏、上海、浙江、福建、广东、广西和海南等省/市沿海近 10km 宽的地带，冬春季的冷空气、夏秋的台风，都能影响到沿海及其岛屿，加上台湾海峡狭管效应的影响，东南沿海及其岛屿是我国风能最佳丰富区。沿海地区经济发达，沿海及其岛屿地区风能资源丰富，风电场接入系统方便，与水电具有较好的季节互补性。然而沿海岸的土地大部份已开发成水产养殖场或建成防护林带，可以安装风电机组的土地面积有限。

内陆风能丰富点。在内陆一些地区由于湖泊和特殊地形的影响，形成一些风能丰富点，如鄱阳湖附近地区和湖北的九宫山和利川等地区。

海上风能丰富区。我国海上风能资源丰富，东部沿海水深 2m 到 15m 的海域面积辽阔，按照与陆上风能资源同样的方法估测，10m 高度可利用的风能资源约是陆上的 3 倍，即 7 亿多 kW，而且距离电力负荷中心很近。随着海上风电场技术的发展成熟，经济上可行，将来必然会成为重要的可持续能源。

二、风电的发展

2.1 建设规模不断扩大，风电场管理逐步规范

1986 年建设山东荣成第一个示范风电场至今，经过近 20 多年的努力，风电场装机规模不断扩大截止 2004 年底，全国建成 43 个风电场，安装风电机组 1292 台，装机规模达到 76.4 万 kW，居世界第 10 位，亚洲第 3 位（位于印度和日本之后）。另外，有关部门组织编制有关风电前期、建设和运行规程，风电场管理逐步走向规范化。

2.2 专业队伍和设备制造水平提高，具备大规模发展风电的条件

经过多年的实践，培养了一批专业的风电设计、开发建设和运行管理队伍，大型风电机组的制造技术我国已基本掌握，主要零部件国内都能自己制造。其中，600kW 及以下机组已有一定数量的整机厂，初步形成了整机试制和小批量生产。截止 2004 年底，本地化风电机组所占市场份额已经达到 18%，设备制造水平不断提高，目前，我国已经具备了设计和制造 750kW 定桨距定转速机型的能力,相当于国际上二十世纪 90 年代中期的水平。与国外联合设计的 1200 千瓦和独立设计的 1000 千瓦变桨距变转速型样机于 2005 年安装，进行试验运行。

2.3 风力发电成本逐步降低

随着风电产业的形成和规模发展，通过引进技术，加速风电机组本地化进程以及加强风电场建设和运行管理，我国风电场建设和运行的成本逐步降低，初始投资从 1994 年的约 12000 元/kW 降低到目前的约 9000 元/kW。同时风电的上网电价也从超过 1.0 元/kW•h 降低到约 0.6 元/kW•h。

2.4 2003 年国务院电价改革方案规定风电暂不参与市场竞争，电量由电网企业按政府定价或招标价格优先购买。国家发展改革委从 2003 年开始推行风电特许权开发方式，通过招投标确定风电开发商和上网电价，并与电网公司签订规范的购电协议，保证风电电量全部上网，风电电价高出常规电源部分在全省范围内分摊，有利于吸引国内外各类投资者开发风电。

2.5 2005 年 2 月 28 日通过的《中华人民共和国可再生能源法》中规定了“可再生能源发电项目的上网电价，由国务院价格主管部门根据不同类型可再生能源发电的特点和不同地区的情况，按照有利于促进可再生能源开发利用和经济合理的原则确定”,“电网企业为收购可再生能源电量而支付的合理的接网费用以及其

他合理的相关费用，可以计入电网企业输电成本，并从销售电价中回收。”和“电网企业依照本法第十九条 规定确定的上网电价收购可再生能源电量所发生的费用，高于按照常规能源发电平均上网电价计算所发生费用之间的差额，附加在销售电价中分摊”，将风电特许权项目中的特殊之处已经用法律条文作为通用的规定，今后风电的发展应纳入法制的框架。

三、存在问题

3.1 资源

需要进行第二轮风能资源普查，在现有气象台站的观测数据的基础上，按照近年来国际通用的规范进行资源总量评估，进而采用数值模拟技术编制高分辨率的风能资源分布图，评估风能资源技术可开发量。更重要的是应该利用 GIS（地理信息系统）技术将电网、道路、场址可利用土地，环境影响、当地社会经济发展规划等因素综合考虑，进行经济可开发储量评估。

3.2 风电设备生产本地化

现有制造水平远落后于市场对技术的需求，国内定型风电机组的功率均为兆瓦级以下，最大 750 千瓦，而市场需要以兆瓦级为主流。国内风电机组制造企业面临着技术路线从定桨定速提升到变桨变速，单机功率从百千瓦级提升到兆瓦级的双重压力，技术路线跨度较大关。

自主研发力量严重不足，由于国家和企业投入的资金较少，缺乏基础研究积累和人才，我国在风力发电机组的研发能力上还有待提高，总体来说还处于跟踪和引进国外的先进技术阶段。目前国内引进的许可证，有的是国外淘汰技术，有的图纸虽然先进，但受限于国内配套厂的技术、工艺、材料等原因，导致国产化的零部件质量、性能需要一定时间才能达到国际水平。购买生产许可证技术的国内厂商要支付昂贵的技术使用费，其机组性能价格比的优势在初期不明显。

在研发风电机组过程中注重于产品本身，而对研发过程中需要配套的工作重视不够。由于试验和测试手段的不完备，有些零部件在实验室要做的工作必须总装后到风电场现场才能做。风电机组的测试和认证体系尚未建立。

风电机组配套零部件的研发和产业化水平较低，这样增加了整机开发的难度和速度。特别是对于变桨变速型风机，国内相关零部件研发、制造方面处于起步阶段，如变桨距系统，低速永磁同步发电机，双馈式发电机、变速型齿轮箱，交直交变流器及电控系统，都需要进行科技攻关和研发。

3.3 成本和上网电价比较高

基本条件设定：根据目前国内风电场平均水平，设定基本条件为：风电场装机容量5万千瓦，年上网电量为等效满负荷2000小时，单位千瓦造价8000－10000

元，折旧年限 12.5 年，其他成本条件按经验选取。

财务条件：工程总投资分别取 4 亿元（8000 元/千瓦）、4.5 亿元（9000 元/千瓦）和 5 亿元（10000 元/千瓦），流动资金 150 万元。项目资本金占 20%，其余采用国内商业银行贷款，贷款期 15 年，年利率 6.12%。增值税税率为 8.5%，所得税税率为 33%，资本金财务内部收益率 10%。

风电成本和上网电价水平测算：

按以上条件及现行的风电场上网电价制度，以资本金财务内部收益率为 10%为标准，当风电场年上网电量为等效满负荷 2000 小时，单位千瓦造价 8000～10000 元时，风电平均成本分别为 0.373～0.461 元/千瓦时，较为合理的上网电价范围是 0.566～0.703 元/千瓦时（含增值税）。成本在投产初期较高，主要是受还本付息的影响。当贷款还清后，平均度电成本降至很低。

风电场造价对上网电价有明显的影响，当造价增加时，同等收益率下的上网电价大致按相同比率增加。

我国幅员辽阔，各地风电场资源条件差别很大，甚至同一风电场址内资源分布也有较大差别。为了分析由风能资源引起的发电量变化对成本和平均上网电价的影响，分别计算年等效满负荷小时数为 1400、1600、1800、2200、2400、2600、2800、3000 的情况下发电成本见表 1，上网电价见表 2。

表 1　不同风能资源条件下的发电成本（元/千瓦时）

等效满负荷小时数 / 投资	1400	1600	1800	2000	2200	2400	2600	2800	3000
8000 元/千瓦	0.533	0.466	0.414	0.373	0.339	0.311	0.287	0.266	0.249
9000 元/千瓦	0.596	0.521	0.464	0.417	0.379	0.348	0.321	0.298	0.278
10000 元/千瓦	0.659	0.577	0.513	0.461	0.419	0.385	0.355	0.330	0.308

表 2　不同风能资源条件下的上网电价（元/千瓦时）

等效满负荷小时数 / 投资	1400	1600	1800	2000	2200	2400	2600	2800	3000
8000 元/千瓦	0.810	0.708	0.630	0.566	0.515	0.472	0.436	0.405	0.378
9000 元/千瓦	0.907	0.794	0.705	0.635	0.577	0.529	0.488	0.454	0.423
10000 元/千瓦	1.005	0.879	0.781	0.703	0.639	0.586	0.541	0.502	0.469

如果全国风电的平均水平是每千瓦投资 9000 元，以及资源状况按年上网电量为等效满负荷 2000 小时计算，则风电的上网电价约每千瓦时 0.63 元，比于全国火电平均上网电价每千瓦时 0.31 元高一倍。

3.4 电网制约

风电场接入电网后，在向电网提供清洁能源的同时，也会给电网的运行带来一些负面影响。随着风电场装机容量的增加，以及风电装机在某个地区电网中所占比例的增加，这些负面影响就可能成为风电并网的制约因素。

风力发电会降低电网负荷预测精度，从而影响电网的调度和运行方式；影响电网的频率控制；影响电网的电压调整；影响电网的潮流分布；影响电网的电能质量；影响电网的故障水平和稳定性等。

由于风力发电固有的间歇性和波动性，电网的可靠性可能降低，电网的运行成本也可能增加。为了克服风电给电网带来的电能质量和可靠性等问题，还会使电网公司增加必要的研究费用和设备投资。在大力发展风电的过程中，必须研究和解决风电并网可能带来的其他影响。

四、政策建议

1. 加强风电前期工作。建立风电正常的前期工作经费渠道，每年安排一定的经费用于风电场风能资源测量、评估以及预可研设计等前期工作，满足年度开发计划对风电场项目的需要。

2. 制定“可再生能源法”的实施细则，规定可操作的政府合理定价，按照每个项目的资源等条件，以及投资者的合理回报确定上网电价。同时也要规定可操作的全国分摊风电与火电价差的具体办法。

3. 加速风电机组本地化进程，通过技贸结合等方式，本着引进、消化、吸收和自主开发相结合的原则，逐步掌握兆瓦级大型风电机组的制造技术。引进国外智力开发具有自主知识产权的机组，开拓国际市场。

4. 建立风电制造业的国家级产品检测中心、质量保证控制体系以及认证制度，不断提高产品质量，降低成本，完善服务。

5. 制定适应风电发展的电网建设规划，研究风电对电网影响的解决措施。

五、“十一五”和 2020 年风电规划

我国电源结构 70%是燃煤火电，而且负荷增长迅速，环境影响特别是减排二氧化碳的压力越来越大，风能是清洁的可再生能源，我国资源丰富，能够大规模开发，风电成本逐年下降，前景广阔。风电装机容量规划目标为 2005 年 100 万千瓦，2010 年 400～500 万千瓦，2020 年 2000～3000 万千瓦。

2004 年到 2005 年，“十五计划”后半段重点建设江苏如东和广东惠来两个特许权风电场示范项目，取得建设大规模风电场的经验，2005 年底风力发电总体目标达 100 万千瓦。

2006 年到 2010 年。“十一五规划”期间全国新增风电装机容量约 300 万千瓦，平均每年新增 60~80 万千瓦，2010 年底累计装机约 400～500 万千瓦。提供这样的市场空间主要目的是培育国内的风电设备制造能力，国家发展改革委于 2005 年 7 月下发文件，要求所有风电项目采用的机组本地化率达到 70%，否则不予核准。此后又下发文件支持国内风电设备制造企业与电源建设企业合作，提供 50 万千瓦规模的风电市场保障，加快制造业发展。

目前国家规划的主要项目有广东省沿海和近海示范项目 31 万千瓦；福建省沿海及岛屿 22 万千瓦；上海市 12 万千瓦；江苏省 45 万千瓦；山东省 21 万千瓦；吉林省 33 万千瓦；内蒙古 50 万千瓦；河北省 32 万千瓦；甘肃省 26 万千瓦；宁夏 19 万千瓦；新疆 22 万千瓦等。目前各省的地方政府和开发商均要求增加本省的风电规划容量。

2020 年规划目标是 2000～3000 万千瓦，风电在电源结构中将有一定的比例，届时约占全国总发电装机 10 亿千瓦容量的 2～3%，总电量的 1～1.5%。

2020 年以后随着化石燃料资源减少，成本增加，风电则具备市场竞争能力，会发展得更快。2030 年以后水能资源大部分也将开发完，近海风电市场进入大规模开发时期。

中国光伏发电的现状和展望

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一、中国光伏发电的战略地位

1.1 中国的能源资源和可再生能源现状和预测；

无论从世界还是从中国来看，常规能源都是很有限的，中国的一次能源储量远远低于世界的平均水平，大约只有世界总储量的 10%。图一给出了世界和中国主要常规能源储量预测。

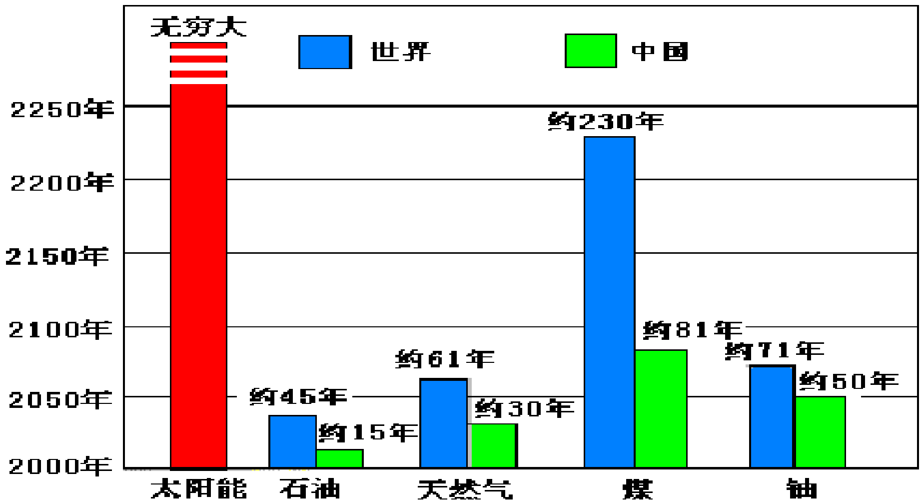


图 1、 世界和中国主要常规能源储量预测（赵玉文）

从长远来看，可再生能源将是未来人类的主要能源来源，因此世界上多数发达国家和部分发展中国家都十分重视可再生能源对未来能源供应的重要作用。在新的可再生能源中，光伏发电和风力发电是发展最快的,世界各国都把太阳能光伏发电的商业化开发和利用作为重要的发展方向。根据欧洲 JRC 的预测，到 2030 年太阳能发电将在世界电力的供应中显现其重要作用，达到 10%以上，可再生能源在总能源结构中占到 30%；2050 年太阳能发电将占总能耗的 20%，可再生能源占到 50%以上，到本世纪末太阳能发电将在能源结构中起到主导作用。图二是欧洲 JRC 的预测。

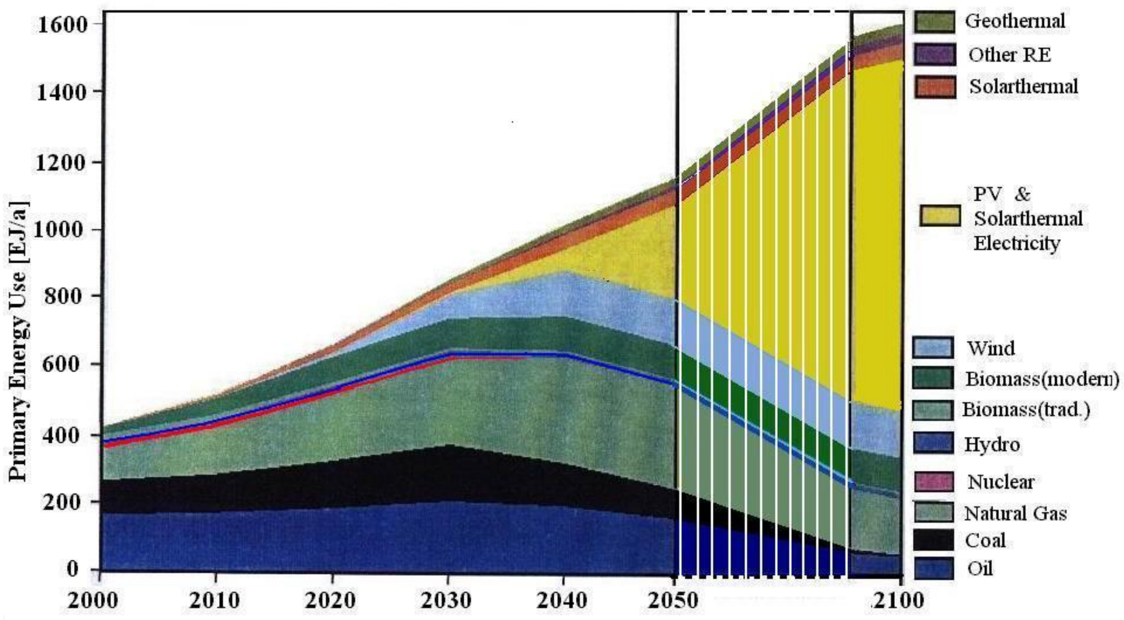


图 2、世界能源发展趋势（PVNET2003）

中国是一个能源生产大国，也是一个能源消费大国。2003 年能源消费总量约为 16.8 亿吨，比 2002 年增长 13%，其中：煤炭占 67.1%、石油占 22.7%、天然气占 2.8%、水电等占 7.3%，石油进口达到 9700 万吨。由于能源需求的强劲增长，煤炭在能源消费结构中的比例有所提高，比 2002 年提高 1 个百分点。图三给出了我国 2003 年一次能源消费构成。

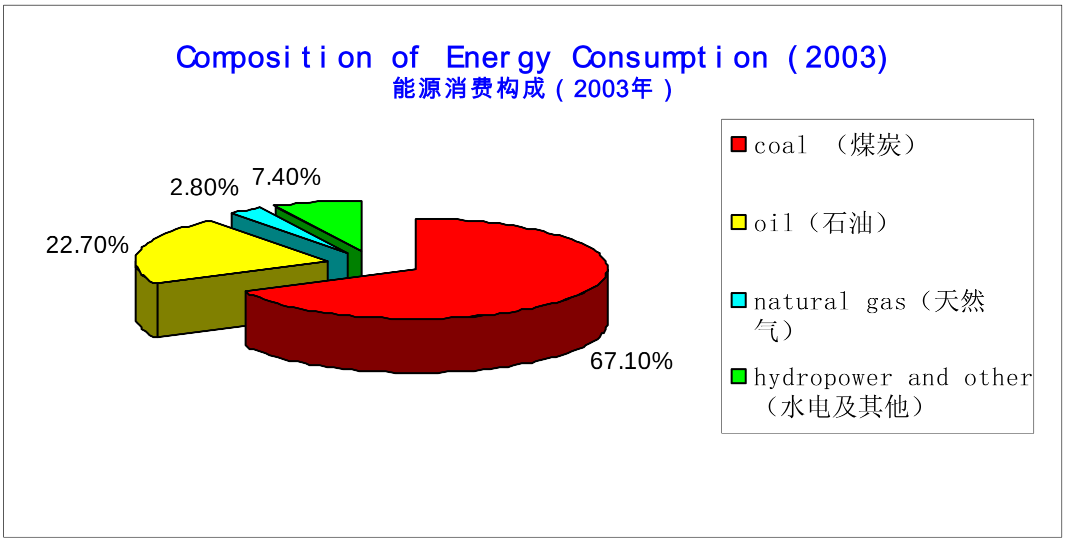


图 4、2003 年中国一次能源消费比例（史立山）

我国政府重视可再生能源技术的发展，主要有水能、风能、生物质能、太阳能、地热能和海洋能等。我国目前可再生能源的发展现状如下：

水能：我国经济可开发的水能资源量为 3.9 亿千瓦，年发电量 1.7 万亿千瓦

时，其中5万千瓦及以下的小水电资源量为1.25亿千瓦。到2003年底，我国已建成水电发电装机容量9000万千瓦，其中小水电容量3000万千瓦。

风能：我国濒临太平洋，季风强盛，海岸线长达18000多公里，内陆还有许多山系，改变了气压的分布，形成了分布很广的风能资源。根据全国气象台风能资料估算，我国陆地可开发装机容量约2.5亿千瓦，海上风能资源量更大，可开发装机容量在7.5亿千瓦,总共可开发装机容量10亿千瓦。目前全国已建成并网风力发电装机容量57万千瓦，此外，还有边远地区农牧民使用的小型风力发电机约18万台，总容量约3.5万千瓦。

太阳能：目前太阳能利用方式主要有热利用和光电利用两种，到2003年底，全国已安装光伏电池约5万千瓦，主要为边远地区居民及交通、通讯等领域提供电，现在已开始进行并网光伏发电系统的试验和示范工作。全国已有太阳光伏电池及组装厂10多家，制造能力超过2万千瓦。到2003年底，全国太阳热水器使用量为5200万平方米，约占全球使用量的40%，年生产量为1200万平方米。

生物质能：生物质能主要有农、林生产及加工废弃物、工业废水和城市生活垃圾等。目前，全国农村已有户用沼气池1300多万口，年产沼气约33亿立方米；大中型沼气工程2200多处，年产沼气约12亿立方米；生物质发电装机容量200多万千瓦。

其它可再生能源：除上述水能、风能、太阳能、生物质能外，还有地热能、海洋能等可再生能源资源。目前所占比例不大。

我国目前新技术利用可再生能源（不含传统秸秆燃烧和5万千瓦以上的大水电）总量为5000万吨标煤，占能源消耗总量3％。

可再生能源是可循环利用的清洁能源，是满足人类社会可持续发展需要的最终能源选择。目前，小水电、风电、太阳热水器和沼气等可再生能源技术已经成熟，生物质供气和发电技术也接近成熟，具有广阔的发展前景。预计今后20-30年内，可再生能源将逐步从弱小地位走向能源主角，将对经济和社会发展做出重大贡献。我国可再生能源2010，2020直至2050年的发展预测如下：

表 1、中国可再生能源发展预测（至 2050 年）

公历年	2003	2010	2020	2030	2050
能源总量（亿吨标煤）	16.8	20	30	40	60
小水电（万千瓦）	3000	5000	7500	10000	20000
年发电量（亿千瓦时）	960	1600	2400	3200	6400
相当于（亿吨标煤）	0.34	0.56	0.84	1.12	2.24
风电（万千瓦）	60.5	400	2000	5000	10000
年发电量（亿千瓦时）	12.7	84	420	1050	2100
相当于（亿吨标煤）	0.0044	0.03	0.15	0.37	0.74
生物质发电（万千瓦）	200	1000	2000	5000	10000
年发电量（亿千瓦时）	100	500	1000	2500	5000
相当于（亿吨标煤）	0.035	0.18	0.35	0.88	1.75
沼气（亿立方米）	45	100	250	300	1000
相当于（亿吨标煤）	0.036	0.08	0.20	0.24	0.80
光热（万平方米）	5200	10000	27000	50000	100000
相当于（亿吨标煤）	0.062	0.12	0.32	0.6	1.2
光电（万千瓦）	5.5	50	3000	4000	10000
年发电量（亿千瓦时）	0.55	7.5	390	540	1400
相当于（亿吨标煤）	0.0002	0.0027	0.14	0.19	0.49
其它（亿吨标煤）	0.027	0.087	1.00	2.60	4.78
合计（亿吨标煤）	0.504	1.0	3	6	12
可再生能源比例（%）	3	5	10	15	20

*:按照 1KWh = 350 克标煤折算

表 2、各种发电形式的年利用小时数比较（李俊峰、顾树华）：

发电形式	年有效利用小时数 （小时）
煤电	5000
核电	6000
气电	4000
大水电	3500
小水电	3000
生物质发电	5000
风电	2100
光电	并网 1300，离网 1100

1.2 中国电力现状和未来电力缺口分析

中国的电力供应在 2000 年以前不紧张，2001 年以后，由于经济发展迅猛，电力需求以每年超过 20％的速度增长，2003 年全国出现电力供应严重不足的现象，电力供应的紧张情况在今后 2－3 年内不会缓解。2002 年全国电力装机 35657 万千瓦，煤电占 74.5％，发电 16542 亿千瓦时，煤电占 81.7％。下表给出了 2002 年我国电力装机和发电情况：

表 3、2002 年中国电力装机和发电情况（电力科学院）

发电方式	装机容量（万千瓦）		发电量（亿千瓦时）	
	容　　量（万千瓦）	占总量百分比（%）	电　　量（亿千瓦时）	占总量百分比（%）
火电	26554	74.5	13522	81.7
水电	8607	24.1	2746	16.6
核电	446	1.25	265	1.6
总计	35657	100	16542	100

按照目前的经济发展趋势和中国的资源情况，2010 年和 2020 年的电力供应单靠传统的煤、水、核是不够的，尚存在一定的缺口，需要由可再生能源发电来填补。

表 4、2010 和 2020 年中国发电装机预测（GW）（电力科学院）

年	煤	水	核	缺口	总计
2010	400	135	12.5	37	584.5
	68.40%	23.10%	2.10%	6.40%	100%
2020	592	220	36	102	950
	62.30%	23.20%	3.80%	10.70%	100%

表 5、2010、2020 和 2050 年中国总电力发展需求预测如下：（电力科学院）

年度	装机容量（亿千瓦）	发电量（亿度）
2002	3.57	16542
2010	5.85	27100
2020	9.50	44000
2050	20.0	92700

表 6、2050 年中国发电装机构成预测（电力科学院）

种类	装机容量 （亿千瓦）	占总量百分比（%）	
煤电	10.0	50%	
核电	2.4	12%	
气电	1.0	5%	
大水电	1.6	8%	
小水电	2.0	10%	可再生能源 25％
生物质发电	1.0	5%	
风电	1.0	5%	
光电	1.0	5%	
总计	20.0	100%	

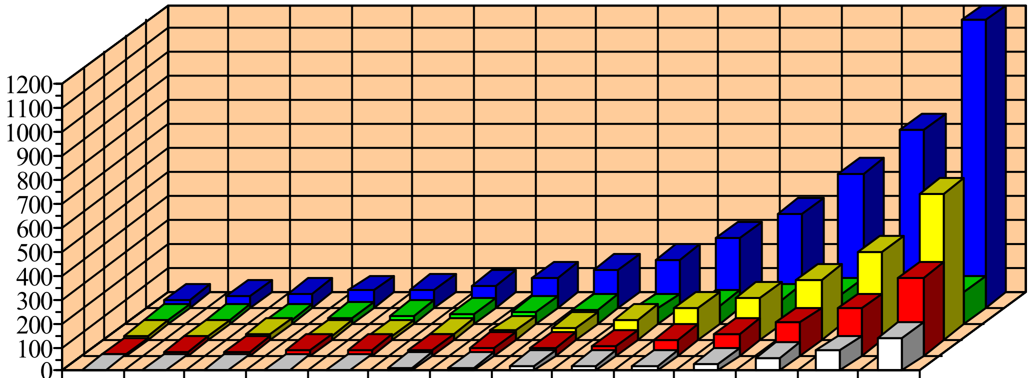
二、世界光伏产业现状和发展预测

太阳电池是利用材料的光生伏打效应直接将太阳能变成电能的半导体器件，也称光伏电池。1954 年，第一块实用的硅太阳电池（ $\eta = 6\%$ ）与第一座原子能发电站同时在美国诞生，1959 年太阳电池进入空间应用，1973 年能源危机后逐步转到地面应用。

光伏发电分为独立光伏系统和并网光伏系统。独立光伏电站包括边远地区的村庄供电系统，太阳能户用电源系统，通信信号电源，阴极保护，太阳能路灯等各种带有蓄电池的可以独立运行的光伏发电系统。

并网光伏发电系统是与电网相连并向电网馈送电力的光伏发电系统。目前从技术上可以实现的光伏发电系统并网的方式有：屋定并网发电系统和沙漠电站系统。屋顶系统是利用现有建筑的屋顶有效面积，安装并网光伏发电系统，其规模一般在几个 kWp 到几个 MWp 不等。沙漠电站则是在无人居住的沙漠地区开发建设大规模的并网光伏发电系统，其规模从 10MWp 到几个 GWp 的规模不等。

近年来，世界太阳电池年产量迅速增加，连续 8 年增速在 30%左右，2004 年的年增长率甚至超过 60%，达到 1200MW。图二给出世界历年太阳电池产量：



	1988	1990	1992	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
其它国家	3	4.7	4.6	5.6	6.35	9.75	9.4	18.7	20.5	23.42	32.6	55	83.8	135
欧洲	6.7	10.2	16.4	21.7	20.1	18.8	30.4	33.5	40	60.66	86.38	135	193.4	320
日本	12.8	16.8	18.8	16.5	16.4	21.2	35	49	80	128.6	171.2	251	363.9	610
美国	11.1	14.8	18.1	25.64	34.75	38.85	51	53.7	60.8	74.97	100.3	120	103.2	135
合计	33.6	46.5	57.9	69.44	77.6	88.6	125.8	154.9	201.3	287.7	390.5	561	744.3	1200

图四、世界太阳电池历年产量（发货量）（PVNET2004）

三、中国光伏发电市场和产业现状

3.1 中国太阳电池的市场发展

我国于 1958 年开始研究太阳电池，于 1971 年成功地首次应用于我国发射的东方红二号卫星上。于 1973 年开始将太阳电池用于地面。我国的光伏工业在 80 年代以前尚处于雏形，太阳电池的年产量一直徘徊在 10KW 以下，价格也很昂贵。由于受到价格和产量的限制，市场的发展很缓慢，除了作为卫星电源，在地面上太阳电池仅用于小功率电源系统，如航标灯、铁路信号系统、高山气象站的仪器用电、电围栏、黑光灯、直流日光灯等，功率一般在几瓦到几十瓦之间。在“六五”(1981－1985)和“七五”(1986－1990)期间，国家开始对光伏工业和光伏市场的发展给以支持，中央和地方政府在光伏领域投入了一定资金，使得我国十分弱小的太阳电池工业得到了巩固并在许多应用领域建立了示范，如微波中继站、部队通信系统、水闸和石油管道的阴极保护系统、农村载波电话系统、小型户用系统和村庄供电系统等。同时，在“七五”期间，国内先后从国外引进了多条太阳电池生产线，除了一条 1MW 的非晶硅电池生产线外，其它全是单晶硅电池生产线，使得我国太阳电池的生产能力猛增到 4.5MWp/年，售价也由“七五”初期的 80 元/Wp 下降到 40 元/Wp 左右。

九十年代以后，随着我国光伏产业初步形成和成本降低，应用领域开始向工业领域和农村电气化应用发展，市场稳步扩大，并被列入国家和地方政府计划，如西藏“阳光计划”、“光明工程”、“西藏阿里光伏工程”、光纤通讯电源、石油管道阴极保护、村村通广播电视、大规模推广农村户用光伏电源系统等。进入 21 世纪，特别是近 3 年的“送电到乡”工程，国家投资 20 亿，安装 20MW，

解决了我国800个无电乡镇的用电问题，推动了我国光伏市场快速、大幅度增长。与此同时，并网发电示范工程开始有较快发展，从5kW、10kW发展到100kW以上，2004年深圳世博园1MW并网发电工程成为我国光伏应用领域的亮点。

截止2004年底，我国光伏系统的总装机容量约达到65MW。

深圳、汕头、广州和浙江等地，大量出口太阳能庭院灯，年销售额达5亿之多。庭院灯用的电池片通常进口，然后用胶封装，工艺简单。所用电池片每年达6MW之多，是太阳电池应用的一个大户(这部分未入统计)。

3.2 中国太阳电池的产业化现状

上世纪七十年代末到八十年代中，我国一些半导体器件厂开始利用半导体工业废次单晶和半导体器件工艺生产单晶硅太阳电池，我国光伏工业进入萌发时期。八十年代中后期，我国一些企业引进成套单晶硅电池和组件生产设备，以及非晶硅电池生产线，使我国光伏电池／组件总生产能力达到4.5MW，我国光伏产业初步形成。九十年代初中期，我国光伏产业处于稳定发展时期，生产量逐年稳步增加。九十年代末我国光伏产业发展较快，设备不断更新。2003年、2004年在我国《送电到乡》工程及国际市场推动下，一批电池生产线、组件封装线、晶硅锭／硅片生产线相继投产和扩产，使我国光伏产业的能力有大幅度上升，我国光伏产业进入全面快速发展时期。截止2004年底，我国光伏产业总的年生产能力为：组件150MW，电池生产67MW，硅锭／硅片生产54MW；生产量约为组件100MW，电池42MW(其中非晶硅4MW)，硅锭／硅片46MW。

最近3年由于《送电到乡》工程和国际市场的推动，我国太阳电池／组件生产迅速增长，2004年的产量是2002年的6倍。电池和组件性能不断提高，商业化电池效率由八十年代的10－12％提高到12－14％。太阳电池／组件成本20年来不断降低，售价由八十年代初的65－70元／Wp降到2003年的24－28元／Wp，2004年由于太阳级硅国际性紧缺，售价又回升到28－32元／Wp。2004年我国太阳电池的实际产量达到50MWp，国内光伏市场消化掉不到10MWp的光伏组件，产品绝大部分出口到国外。

虽然我国光伏产业发展迅速，产业规模和技术水平都有相应提高。但同发达国家相比，仍存在很大差距，如：专用原材料国产化程度不高，品种不全，已经实现国产化的材料和部件，其性能比国外偏低，如银、铝浆、EVA等。组件封装低铁绒面玻璃、TPT尚未投放市场。

光伏产业链上游小、下游大的不平衡状态，其中最严重的是太阳级多晶硅生产是空白，完全依赖进口。其它环节的差额部分需要进口，如电池片、硅锭／硅片，配套材料等，如图5所示。

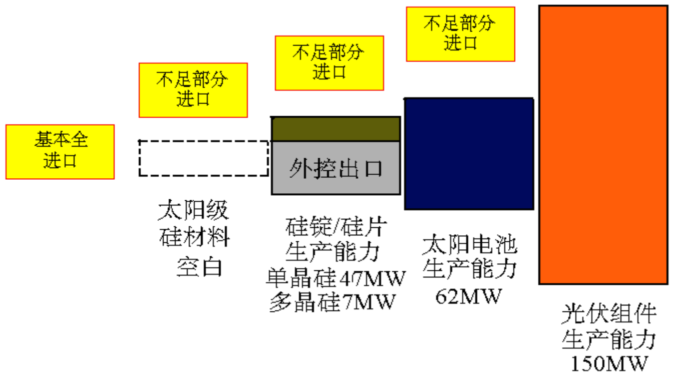


图 5 截止 2004 年底我国光伏产业链(晶硅)发展的不平衡状态

产业设备设计水平和制造能力落后。多晶硅铸造炉、线锯、破锭机完全需要进口；PECVD 氮化硅沉积设备、丝网印刷机、电池片分选机、串联焊接机等性能均不能满足现代化生产需要。这些设备都需要全套引进，等等。

这些差距同研发基础和工业基础薄弱有关。企业通过引进消化吸收能够在短时间内建立起现代光伏产业，但配套的专用材料和设备一时还跟不上，其中太阳级多晶硅材料尤其突出。国家应组织光伏产业同化工、机电设备制造产业联合攻关，同时积极寻求国际合作，以太阳能级硅为切入点，避开半导体级硅的技术封锁。

四、中国光伏发电的市场预测和规划建议

4.1 总体分年度发展目标

“十一、五”以及到 2020 年光伏发展年度规划目标预测如下：

表 7、2004－2010 期间规划累计安装容量（MWp）

年度	2003	2004	2005	2006	2007	2008	2009	2010
年新增		10	27	38	52	75	105	138
累计安装	55	65	92	130	182	257	362	500

平均年增长：41％

表 8、2010－2020 期间规划累计安装容量（GWp）

年度	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
年新增		0.20	0.32	0.48	0.75	1.17	1.82	2.84	4.42	6.87	10.65
累计安装	0.5	0.68	1.00	1.48	2.23	3.40	5.22	8.06	12.48	19.35	30.00

平均年增长：56％

表 9、2003 年中国国内光伏分类市场及份额

市场分类	累计安装量（MWp）	市场份额（%）
农村电气化	28	51
通信和工业	20	36
太阳能光伏产品	5	9
城市 BIPV	2	4
开阔地（荒漠）电站		
合计	55	100

表 10、 规划 2010 年中国国内光伏分类市场及份额

市场分类	累计安装量（MW）	市场份额（%）
农村电气化	300	60
通信和工业	70	14
太阳能路灯	5	2
太阳能光伏产品	25	4
城市 BIPV	70	14
沙漠 / 戈壁电站	30	6
合计	500	100

表 11、 预测 2020 年中国国内光伏分类市场及份额

市场分类	累计安装量(MWp)	市场份额（%）
农村电气化	3000	10.0
通信和工业	4500	15.0
太阳能路灯	1000	3.3
太阳能光伏产品	1500	5.0
城市 BIPV	8000	26.7
沙漠 / 戈壁电站	12000	40.0
合计	30000	100

4.2 “十一、五”建设重点布局

“十一、五”期间，应把实施农村离网光伏发电计划，落实开阔地（荒漠）大型并网光伏电站先导项目以及“中心城市建筑光伏并网”计划作为重点。对于光伏商业化发展也给予政策方面的积极扶持和支持。

4.2.1. 农村离网光伏发电计划

我国还有大约 28,000 个村庄，7 百万户，3,000 万人口无电。这些无电人口大都分布在我国西部地区和一些海岛，其中一些无电村庄使用柴油发电机发电，每日供电 2－3 小时；有些连柴油发电机也没有，只能点酥油灯、煤油灯和蜡烛照明。这些无电地区有很丰富的太阳能资源，光伏发电在这样的地区有广阔的市

场前景。下表列出了中国当前无电村和无电户的分布情况：

表 12、 中国无电村和无电户统计

省／自治区	无电县	无电乡	无电村		无电村总数量	无电户总数量
			行政村	自然村		
西藏	—	486	5,254	—	5,740	289,300
贵州	—	-	3,000	377	3,377	1,294,000
甘肃	—	9	871	2,384	3,264	360,173
内蒙古	—	-	960	2,100	3,060	249,590
福建	—	—	960	1,400	2,360	249,590
青海	1	94	773	1,254	2,121	101,000
四川	—	126	1,459	40	1,625	648,300
新疆	—	28	216	1,095	1,339	316,200
宁夏	—	—	—	1,306	1,306	64,000
湖北	—	—	75	975	1,050	121,500
河南	—	—	700	—	700	577,000
广西	—	—	666	34	700	388,600
云南	—	4	528	—	532	1,003,800
湖南	—	—	—	518	518	279,500
河北	—	—	357	43	400	13,800
陕西	—	11	344	—	355	289,100
山西	—	—	259	—	259	112,000
海南	—	—	253	—	253	160,300
重庆	—	3	163	—	166	191,900
安徽	—	—	17	33	50	80,500
江西	—	—	17	33	50	287,000
黑龙江	—	—	13	—	13	9,100
辽宁	—	—	4	—	4	4,800
广东	—	—	—	—	—	50,800
合计	--	761	16,889	11,592	29,242	7,141,853

无电乡的供电问题已经通过“送电到乡”工程基本解决。还有无电村和无电户需要解决供电问题。如果每个无电村按照 10KWp,每个无电户按照 400Wp 规划，再考虑到已建电站的扩容，则潜在市场大约是 3,000 MWp。

从目前的国力和政策看，2010 年以前，争取全部解决西部 50 户以上的无电村和 15%的散居无电户的用电问题，2006-2010 年间，争取解决 10000 个无电村和 100 万无电户的用电问题,新增光伏用量 265MWp，累计用于农村电气化的太阳电池达到 300 MWp，分年度计划如下：

表 13、 2006－2010 年用于农村离网光伏发电的装机规划（MWp）

年	2003	2004	2005	2006	2007	2008	2009	2010
年装机		2	5	15	30	50	70	100
合计	2006-2010 年新增装机 265MWp							
安装成本（万元/KWp）				7	6.5	6.1	5.6	5.2
新增投资（亿元）				10.5	19.5	30.5	39.2	52
合计	2006-2010 年新增投资　151.7 亿元							
累计装机	28	30	35	50	80	130	200	300
年发电量（GWh）	30.8	33	38.5	55	88	143	220	330

*按照年满功率发电 1100 小时计。

4.2.2. 开阔地大型并网光伏电站建设

从目前的国力和政策看，2010 年以前，应先开展开阔地大型光伏电站试验，所选择的试验地点应当具备如下条件：靠近主干电网（最好在 50 公里以内），以减少新增输电线路的投资；主干电网具有足够的承载能力，在不改造的情况下有能力输送光伏电站的电力；距离用电负荷中心在 100 公里以内，以减少输电损失；如果附近没有用电负荷中心，则最好有大型水电站，可以将光伏电站的电力通过抽水蓄能转换。规划在 2010 年以前建立 2－3 座 10－20MWp 左右的开阔地(荒漠)先导示范电站，总装机达到 30MWp，以实验其技术和经济的可行性。

2010－2020 年正式启动中国开阔地（荒漠）光伏电站计划，争取 2010-2020 年新增光伏电站装机 11,970MWp，到 2020 年底累计开阔地(荒漠)光伏电站装机 12GWp。

表 14、 2006－2010 年用于开阔地电站的装机规划（MWp）

年	2003	2004	2005	2006	2007	2008	2009	2010
年装机			2	4	4	5	5	10
合计	2006－2010 年新增装机 28MWp							
安装成本（万元/KWp）				5	4.7	4.3	4.0	3.7
新增投资（亿元）				2.0	1.88	2.15	2.0	3.7
合计	2006-2010 年新增投资 11.73 亿元							
累计装机			2	6	10	15	20	30
年发电量（GWh）			2.6	7.8	13.0	19.5	26.0	39.0

*：按照年满功率发电 1300 小时计。

五、结论

1、中国有很好的太阳能资源，有足够的建筑屋顶和沙漠／荒漠资源，具有大规模发展光伏发电的条件；

2、光伏将在中国未来的电力供应中扮演重要角色，预计中国光伏工业将以每年不低于 40％ 的速度增长；

3、当前中国光伏工业和光伏市场发展很快，但存在“头小尾大”不平衡的问题，不解决高纯多晶硅原材料和硅片生产的问题，中国光伏工业的发展就会受到限制；

4、中国光伏工业发展的关键在于政策。如果中国的“可再生能源促进法”得以实施，仿效德国的成功经验，中国光伏事业发展的资金障碍是可以消除的。

中国太阳能热利用产业发展现状及前景预测

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2005.10

太阳能热利用就是直接将太阳的辐射能转化为热能的应用。目前在中国的研究和应用主要包括太阳热水器、太阳房、太阳灶、太阳干燥、太阳海水淡化及其它工农业应用。到 2004 年，上述各种应用的发展总体情况如下表所示：

项目 / 状况	太阳能热水器（万平方米）	太阳房（万平方米）	太阳灶（万台）	太阳干燥	海水淡化	工农业生产应用
年生产量	1350			示范性装置	示范性装置	示范性装置
总保有量	6200	2000	50			

由上表可见，太阳能热水器已经发展成为具有一定生产规模和巨大应用市场的产业，本文对此将予以重点介绍。

一、中国太阳热水器产业发展现状

简要发展历程

中国太阳能热利用起源于上世纪 70 年代。20 世纪 80 年代，由于能源紧张引起国家和社会重视，国内许多科研院所、大专院校开始从事太阳能热利用的研究工作，以平板太阳热水器、闷晒热水器产品为主的一些生产制造企业相继诞生，但发展比较缓慢。。从“七五”至“十五”的科技攻关，将一大批科研成果转化为生产力，如：铜铝复合平板太阳集热器、全玻璃真空管太阳集热器及热水器，热管式真空管热水器等，尤其是立式单靶磁控溅射铝-氮／铝全玻璃真空太阳集热管技术的成功转化，全面带动了我国太阳能热利用的产业化进程。1996 年以前，太阳热水器产品以平板型为主，占 70%以上。1996 年后，真空管型太阳热水器逐步成为市场主导产品，现已经占到 87.5%以上。

产业发展状况

产业：太阳能热水器是我国太阳能利用中应用最广泛、产业化发展最迅速的太阳能产品。由我国自主开发生产的全玻璃真空管太阳集热器的科技水平、制造技术、生产规模均处于国际领先水平，且生产成本低廉，具有较强的国际竞争力。

我国太阳热水器企业 300 余家，年产值 120 多亿元，初步形成了原材料加工、产品开发制造、工程设计和营销服务的产业体系，有力地带动了玻璃、金属、保

温材料和真空加工设备等相关行业的发展，成为一个产业规模迅速扩大的新兴产业。

产量：我国的太阳热水器产业进入 20 世纪 90 年代后期以来发展迅速，生产量由 1998 年 350 万平方米增长到 2004 年的 1350 万平方米/年，热水器的总保有量由 1998 年的 1500 万平方米增长到 2004 年的 6200 万平方米，户均占有率达到 7.8%，销售额达 200 多亿元，形成一定的产业规模。

表 1--1　1998 年－2004 年太阳热水器总产量、总保有量

年份	年产量（万平方米）	比上年增长（%）	保有量（万平方米）	比上年增长（%）
1998	350		1500	
1999	500	43	2000	33
2000	640	28	2600	30
2001	820	28	3200	23
2002	1000	22	4000	25
2003	1200	20	5000	25
2004	1350	12.5	6200	24

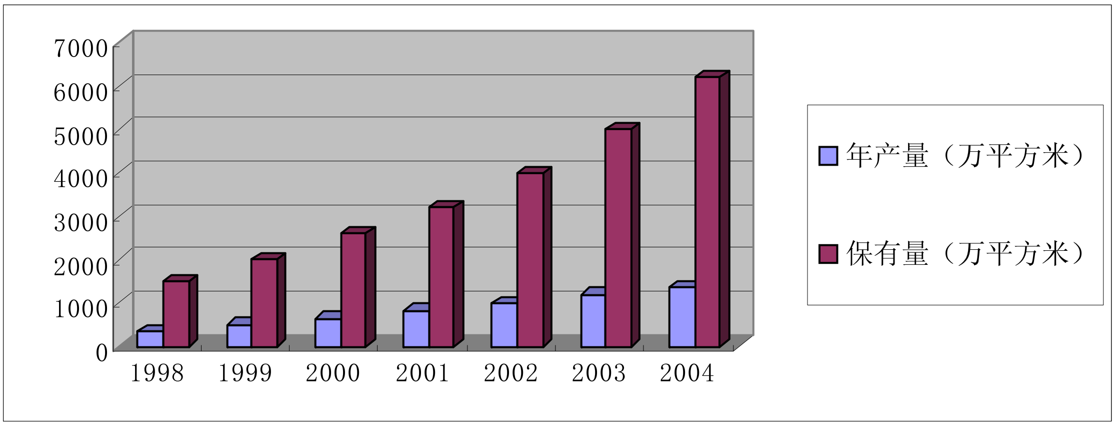

图 1--1　1998 年－2004 年太阳热水器总产量与总保有量变化

产品：目前我国的太阳热水器品种主要有真空管、平板、闷晒式三大类。2004 年，我国年太阳热水器总产量达到 1350 万平方米。其中真空管热水器产量为 1180 万平方米，占总产量的 87.5%，平板热水器产量为 152.5 万平方米，占总产量的 11.3%，闷晒型热水器产量为 16.2 万平方米，占总产量的 1.2%。

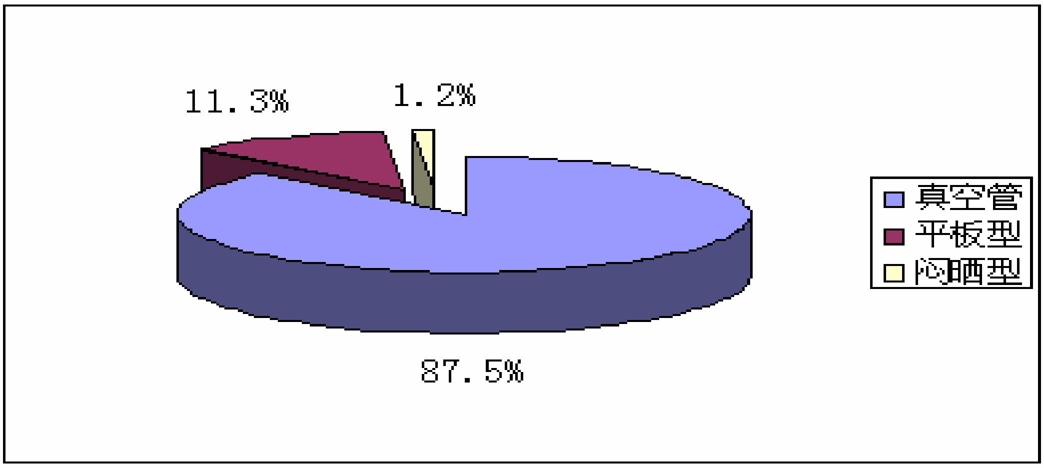

图 1--2　2003 年太阳热水器产品结构

由我国自行研制和开发的全玻璃真空管太阳热水器是国内目前的主流产品。2001 年全玻璃真空管热水器，总产量为 638 万平方米，比 2000 年增长 61.1%。2002 年总产量达到 855 万平方米，同比增长 34%。2003 年总产量为 1050 万平方米，同比增长 22.8%。其中热管真空管热水器 10 万平方米左右。

市场：太阳热水器市场的发展进入快速增长、良性发展的阶段。2001 年热水器总销量 780 万平方米，比 2000 年增长 27.8%；2002 年总销量达到 960 万平方米，同比增长 23.1%。2003 年总销量 1140 万平方米，同比增长 18.8%. 我国太阳热水器目前已进入国际市场，出口 30 多个国家，2004 年出口额达千万美元。

表 1--2　1998－2003 年太阳热水器销售总量

年份	销售量（万平方米）	比上年增长%
1998	340	
1999	480	41
2000	610	27
2001	780	27.8
2002	960	23.1
2003	1140	18.8

1.3 太阳热水器的工程化应用

- 户用太阳热水器已成为家庭用热水的主体

由于采用太阳能为热源，运行、使用费用相比于其它产品低的多，太阳热水

器产品的诸多种类又满足了不同用户的热水需求，所以户用太阳热水器的市场占有率在稳步上升。2001 年三种热水器全国家庭占有率分别为：燃气热水器 20.5%，电热水器 11.2%，太阳热水器 5.7%（以 2001 年保有量推算）。预计到 2004 年三种热水器占有率将分别达到 22.9%、15.4%和 12.3%，太阳热水器已三分天下，市场份额举足轻重。

- **太阳能热水器与建筑结合的工程化应用是实现建筑节能的重要措施**

2002 年我们国家建筑能耗占总能耗的 27.5%，折合成标煤就是 4.5 亿吨左右，到 2020 年，建筑能耗的比例大概能占到 23%～25%左右，约是 7.6～7.9 亿吨标煤，预计到 2010 年，太阳热水器集热面积达到 1.5 亿 m^2，年替代能源 2500 万吨标准煤，若太阳热水器总量达到 3.0 亿 m^2，年替代能源 5000 万吨标准煤。太阳热水器的替代量占到了建筑总能耗的 6.5%左右，是现在的 6 倍；是 2020 年能源总量 30 亿吨标煤的 1.6%，可见太阳能对建筑节能和总能源需求的贡献是很大的。

在国家政策的支持下，全国各地建成了很多太阳能示范小区。随着太阳能与建筑结合的试点工作取得较好成效，商业化的需求也在逐渐增长。在建筑中，如学校、宾馆、洗浴中心和住宅小区采用太阳热水器提供生活热水不断增加，厂家和经销商都在积极推广太阳热水器在工程上的应用（集体安装或热水工程）。太阳能热水器工程化应用正在起步，必将有一个大的发展。

- 采暖空调的应用

太阳能采暖、空调技术已经开始迈入实用化阶段。1998 年 1 月，中科院广州能源研究所研制成功了实用型太阳能空调热水系统，在广州江门市投入运行。其中，制冷用热水温度 65℃～75℃，生活热水温度 55℃～60℃，采用 500 平方米高效率平板集热器，一台 100kW 两级吸收式制冷机，可满足超过 600 平方米的空调负荷。北京市太阳能研究所在山东省乳山市建成 100kw 太阳能空调系统，采用热管式真空管集热器、中温运行的单级吸收式制冷机；2003 年在本单位也建成 100 千瓦太阳能光伏发电和 300 千瓦太阳能采暖空调两个综合示范系统，建筑物顶层完全采用太阳能为其供电、空调、采暖和供生活热水。本示范项目将为太阳能利用与建筑物相结合，为太阳能光电、光热综合利用积累经验和数据，充分展示了太阳能利用的魅力。北京天普太阳能工业有限公司在北京奥运科技专项“新能源综合利用建筑研究示范”的课题，采用了真空管空气集热器在夏季组织通风，冬季产生热空气来解决中庭的热环境问题，为今后的太阳能与建筑结合利用提供了丰富的借鉴经验。

二、发展前景预测

太阳热水器是一种具有节能、环保、经济、使用方便的绿色能源产品，应用

太阳热水器是解决我国广大居民生活用低温热水和工农业生产低温用热的现实、经济、有效的途径，具有广泛的发展空间和巨大的市场潜力；太阳能空调及采暖、热水器技术与建筑相结合，是减小建筑能耗的一条行之有效、绿色环保的可持续发展之道，对我们这个能源资源缺口较大的发展中国家来说，具有重大的意义。

2.1 重点研究开发的技术及产业发展方向和重点领域

2.1.1 低温热水技术的研究

- **平板集热器**

a. 采用优质集热板芯，逐步发展高质全铜板芯；

b. 采用优质选择性涂层；

c. 盖板要求采用高透过率材料；

d. 采用推广透明隔热材料以抑制对流，减少热损失；

e. 开发建筑屋面模块式集热器。

- **全玻璃真空管集热器**

a. 发展内置金属流道的玻璃真空集热器；

b. 热管真空管；

- **闷晒热水器**

a. 发展研制不同档次的闷晒热水器；

b. 发展真空管闷晒热水器。

- **太阳热水系统**

a. 发展各种全年全天候的太阳热水系统，例如带换热器的二次循环系统并配有辅助热源，质量与国际相当；

b. 开发太阳热水系统的应用软件和硬件（零部件）。

到 2020 年太阳能低温热水技术，不论在水平上，还是科技、产业化、规模上要居国际先进水平，成为国际太阳能低温设备加工、进出口基地；

太阳能采暖和空调要达到实用化，科技成果向生产力转化，大面积推广应用，基本实现产业化。

2.1.2 中高温技术的开发和研究

开发太阳能热利用的中高温技术，在海水淡化及工农业应用的其它领域推广使用太阳能热利用技术；

进行太阳能热发电技术的研发，引进相关设备与技术，并努力实现国产化，争取 2010 年前建立兆瓦级太阳能热电站。

到 2015 年太阳能的中高温利用技术要达到和接近国际水平。

2.1.3 产业发展方向和重点领域

发展方向

- 进入建筑业是加速产业发展和规范太阳热水市场的重要途径；
- 扩大太阳热水使用范围，通过示范向其他适用领域发展；
- 扩大农村和中小城镇居民的低温用热水需求，应是太阳热水器的主要市场方向。

重点领域：

- 太阳能集热器及其热水工程系统
- 太阳能与建筑结合集成技术
- 太阳能采暖空调技术和储热技术
- 主动式太阳房技术
- 太阳能海水淡化技术
- 太阳能干燥技术及其它工农业应用
- 太阳能中高温利用技术（热发电）

2.2 市场发展预测

太阳能热利用市场潜力巨大

- **太阳热水器以其节能、环保的性能，受到广大用户的青睐**

经过二十多年的改革开放和发展，我国社会生产力、综合国力和人民生活水平都上了一个大台阶， 随着国民经济和人民生活水平的不断提高，居民对家庭室内热水的需求越来越强烈。据研究测算，到2020年，当我国进入小康社会时，人均每天需要生活热水约40kg， 全国年需求量将达到约200亿吨。届时我国太阳热水器保有量达到3亿m^2，可产生生活热水130亿吨，可节省电力约1350亿千瓦时，占需求量的65%。

年份	年产量（万m^2）	累计量（万m^2）	我国人口（亿）	每千人占有量（m^2）
2004	1100～1200	6200	13	47
2010	2600～3000	15000	13.71	109
2020	4500～5000	30000	14.3	210

- **和建筑的结合将进一步拉动市场**

“十五”期间我国建筑业与房地产业将以较快的速度发展，全国预计累计完成城镇住宅竣工面积27亿平方；2005年城镇居民人均住房建筑面积增加到22平方米，城市实现户均一套功能基本齐全的住宅。随着太阳热水器与建筑结合的进一步完善，实现对建筑能耗6.5%的贡献率指日可待，这将极大的推动太阳热水器在建筑上应用的市场。

- **小城镇建设开拓更大市场**

中国有13亿人口，75%生活在农村，这是太阳能利用的巨大市场。改革开放以来，农村经济增长很快，大量的农宅和小城镇住宅对生活热水的需求大大增加。

2000 年我国村镇房屋建筑总面积约 175 亿平方米，在此后 15 年内将新增 85 亿平方米，这样村镇总住宅建筑面积达到 260 亿平方米。到 2020 年，如果农村太阳热水器的普及率达到了 25%，全国农村太阳热水器的拥有量将达到 1.7 ～1.8 亿平方米，占全国总量的 60%左右，对保护生态环境，防止水土流失，积极妥善解决农村小康生活用能问题起到重要作用。分散的村镇采用天然气或电能作为日用能源，无论在技术还是在经济上都是不可取的，这些都为开辟农村太阳热水器市场提供了机遇。

2.3 形成成熟的具有国际竞争力的民族产业

太阳热水器作为一个新兴产业，随着技术和市场的不断发展，国家有关部门也在进一步提高认识，加大宏观管理和指导力度，培育太阳热水器产业成为国民经济新的增长点。推动太阳热水器产业发展的指导思想是以市场为导向，以企业为主体，以技术进步为支撑，加强宏观指导，培育和规范市场，逐步实现企业规模化，产品标准化，技术国产化和市场规范化。

国家有关部门和地方各级有关部门已开始将太阳热水器科技开发和创新纳入其科技发展规划，逐步加大对技术、新产品科研开发的支持力度，提高科技成果转化率；鼓励企业与大专院校、科研单位实行产学研联合，开发太阳能热利用新技术和新产品；鼓励企业加大对科技开发的投入力度，推动建立以企业为主体的技术开发和技术创新体系，逐步提高企业自主创新能力。

国家有关部门正在积极组织实施重大技术示范，支持企业提高装备水平，提高产品质量和生产率，降低生产成本；鼓励企业不断开发新技术、新产品，增加产品品种和规格，扩大推广应用范围，形成一批用户信得过、国内外有较高信誉的名牌产品；引导产业结构和产品结构调整，鼓励和支持从事太阳热水器工程、安装、服务的第三产业发展。通过宏观调控和市场引导，促进产业升级，形成具有国际竞争力的民族产业。

三、中国太阳热水器产业及市场发展的保证体系

3.1 技术开发和科技进步的保证体系

- 技术开发与投入

中国太阳热水器从产业发展之初就受到国家的重视。国家和地方政府设立了一系列关于可再生能源与太阳能热利用的科研开发项目，不断加大科技投入，如科技攻关、863 计划、973 计划、自然科学基金等。仅国家在“七五”、“八五”、九五”和“十五”四个五年计划期内，分别投入科技攻关经费为：3 千万、3 千万、6 千万和 4 千万人民币，“十五”期间 863 计划投入 1.8 亿人民币，其中太阳热水器科技攻关为重要内容之一。在技术上取得了许多重大成果，例如真空管

技术是“七五”成果，“八五”期间开始形成产业，目前已占热水器产品总量87.5%以上。

- 资金和信贷支持

中国太阳热水器行业的快速发展与政府财政的积极支持是分不开的。国家以技改贷款、国债基金等方式不断加大该行业的投入，实施产、学、研一体化开发计划。1987-1997 年，每年国家拨出 1.2 亿元的技改贷款扶持可再生能源企业的技改，其中也包括了一批太阳能行业内的骨干企业；2002 年，国家又利用计改贷款和国债基金共 1.75 亿元支持皇明公司 1.3 亿元，辉煌公司 3000 万元，丽光公司 1500 万元，促进生产线改造和进行产业升级；一些地方政府也给予了相应财政支持，如北京拨款 800 万元给桑普太阳能技术公司，重庆贷款 5000 万给北陪玻璃仪器总厂等等。

- 建立以企业为主体的研发中心

中国太阳热水器行业在国家相关政策的积极引导下，从无到有，基本形成了以企业为主导的，以高校和国家研究机构为支撑的自主研究开发体系。如清华阳光自主开发立式单靶磁控溅射铝—氮/铝选择性吸收涂层技术（国家发明专利），建立比较健全的产品研发中心；山东皇明与中国科学院工程热物理所合作建立皇明中科实验室，并与澳大利亚悉尼大学建立了共同研究开发合作关系；山东力诺与德国帕尔德克玛成立合作开发公司；北京桑普继续完善了太阳能热利用研发测试体系；其他企业也在逐渐创造条件和筹备建立本企业研发机构。整个产业拥有自己的核心技术与知识产权。

3.2 产品质量保证体系

- 太阳热水器标准化体系初步形成

到目前为止，我国已颁布 16 项太阳热水器国家标准，以及 3 项行业标准，初步构成了我国太阳热水器技术标准体系，为我国太阳热水器产业发展和市场规范提供了技术法规依据。

- 初步形成检测和认证体系

为促进我国太阳热水器产业的健康发展，加速中国太阳热水器行业商业化能力建设。原国家经贸委在联合国开发署（UNDP）/全球环境基金（GEF）“加速中国可再生能源商业化能力建设”项目中，支持国家级太阳热水器质检中心的建设并开展产品认证工作。目前已在北京、武汉、昆明建成三个中国太阳热水器产品质量检测中心，并在北京建成中国太阳热水器产品认证中心，并于 2004 年全面投入运行，我国太阳热水器产品质量进入有法可依、监督执行的阶段。

3.3 国家立法

在 2005 年 2 月 28 日第十届全国人民代表大会常务委员会第十四次会议通过

了《中华人民共和国可再生能源法》，将于 2006 年元月 1 日起实施。该法的实施对太阳能等可再生能源的发展提供了最可靠的法律保证，并将为太阳能热水器产业带来新的机遇，促成新一轮的产业发展态势。

四、问题和建议

4.1 加大新技术新产品开发推广力度，提高企业技术开发能力和技术装备水平、鼓励和支持产业升级和技术进步

坚持科技进步和科技创新，不断完善和提高我国太阳能低温热利用技术水平，开发新技术新工艺和新产品，为产业发展服务。促进我国太阳能热利用产业持续、快速、健康发展。在产业规模上，要继续保持国际领先地位，在技术水平上也要赶上和达到国际先进水平。

开发太阳能与建筑结合的集成技术，包括工程规划、设计与工艺技术、与常规能源互补技术、控制技术，使太阳能成为安全、稳定、可靠的在建筑上应用的低温供热能源。太阳能与建筑结合，建筑也必须是节能建筑。主、被动式太阳房就是节能效果极为显著的节能建筑，国家有关部门应给予高度重视，特别是在我国广大农村应予以大力推广。

要扩大太阳能低温热利用技术应用，积极开展太阳能采暖制冷空调的技术开发和试验、海水淡化技术及其它工农业生产应用的技术开发。

4.2 开展国际合作，引进和消化、吸收国外高效太阳能集热、储热的新材料、新工艺、新技术，如高效涂层技术、隔热透过新材料等，并实现国产化。

跟踵国际太阳能热利用科技前沿，集中优势开展太阳能中高温利用技术的基础研究和应用研究。

要建立以企业为主体的我国太阳能热利用科技研究和开发体系，建立国家级太阳能热利用开放实验室，吸收国内人才，开展新技术、新材料、新方法的研究和试验；选择并支持有条件的大型企业建立研究开发中心，使我国的太阳热利用的科学技术达到国际前沿水平。

4.3 规范太阳热水器产品市场

各级市场管理部门要加强监督，严格执法，依法管理，打击假冒伪劣产品；杜绝乱检测、乱收费、乱罚款和地方保护；国家不鼓励实行太阳热水器产品生产许可证和准销证，各地不得以此为由对产品正常流通加以限制或实行检测、收费、罚款；各地应积极引导和要求企业执行相关国家标准，对通过国家检测机构检测并符合标准的产品，不得再以其它名义开展重复检测；各地要督促企业严格执行产品质量法、反不正当竞争法、保护消费者权益法等法律法规。

4.4 引导和鼓励企业建立现代企业制度、运行机制和管理机制，提高企业管

理水平和综合实力

鼓励和推进太阳能行业内企业资源重组、整合、规模经营；扶持一批具有自主知识产权和国际竞争力的骨干企业。

4.5 搞好宣传普及，加大培训和信息传播力度

利用多种方式和各种媒体广泛向社会宣传利用太阳能的意义和作用，普及太阳热水器知识，推介新技术、新产品；适度举办与产业发展相适应的产品展览、展销会和广告宣传；加大对建筑行业关于太阳能与建筑结合应用技术的宣传。

加强对相关标准、检测等方面的宣传贯彻工作。对从事太阳热水器技术、管理和销售的人员进行有计划、有组织地培训，促进交流，提高业务素质和水平。多渠道、多形式加速培养各类专业人才，全面提高行业的竞争力。

加强统计体系建设和信息交流，支持行业和企业的信息化工作，通过信息传播，引导产业健康发展。

4.6 太阳能热利用专项立法

国内外的经验证明，若是新能源和可再生能源的利用取得发展和进步，都必须得到国家的支持，其最有效的办法就是立法。目前我国已有《可再生能源法》，但不够，还必须有各种可再生能源专项法，如“太阳能利用法”；在各种专项立法中应明确给予热能、燃料、油料等各种能源品种与电力开发同等的优惠扶持政策。各地方也可以依据自身的资源、经济、社会条件和可再生能源产业发展的实际状况制定地方性的某种可再生能源法。

中国生物质发电发展未来展望

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生物质是重要的可再生能源资源，是替代和接续石油、天然气等常规能源的主要战略能源资源之一。生物质发电是生物质清洁、高效利用的重要技术，具有发电效率高、保护和改善生态环境等优点。世界各国的研究和应用示范表明，先进的生物质发电技术的发电效率已达 40%以上，能源利用效率高。而在生物质的再生利用过程中，排放的 CO2 与生物质再生时吸收的 CO2 达到碳平衡，具有 CO2 零排放的作用，对缓解和最终解决温室效应问题将具有重要贡献。我国的生物质资源丰富，在我国生产的一次能源中生物质能占 15%左右，仅次于煤炭居第二位，特别是在农村，仍有 30%的能源来自生物质能。

一、生物质资源状况

我国的生物质种类很多，主要包括农业废弃物、薪柴、林业废弃物、有机废弃物（如禽畜排泄物和城市生活垃圾）、工业废弃物（如谷物加工厂、造纸厂、木材厂、糖厂、酒厂和食品厂等产生的废弃物）。其结构组成归纳如图 1 所示，农业废弃物是中国最大的生物质能资源，占总量的一半以上。这些生物质蕴藏的能量非常巨大，估计中国每年的生物质能源总量达 4.87 亿吨油当量，其中有约 3.7 亿吨可用于发电和供热，占总量的 76%，其余的 1.17 亿吨在农村地区则用作饲料、粪肥等其他用途。

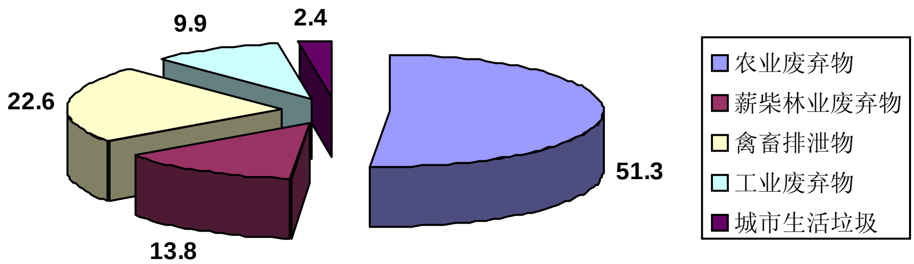

图 1　中国的生物质能资源结构（%）（总量 4.87 亿吨油当量）

1.1 农业废弃物

我国是农业大国，在稻谷、麦子、玉米、豆类、块茎作物、棉花和甘蔗等农作物生产过程中产生大量的农业废弃物，是中国生物质资源的重要来源之一。以

2001 年为例，它们产生的农业废弃物 7.15 亿吨，折合能源约 2.5 亿吨油当量。图 2 所示为各类农作物废弃物的能源潜力，其中，稻谷、麦子和玉米是中国三大粮食作物，它们产生的农业废弃生物质占农业废弃物总量的比例高达 70%。

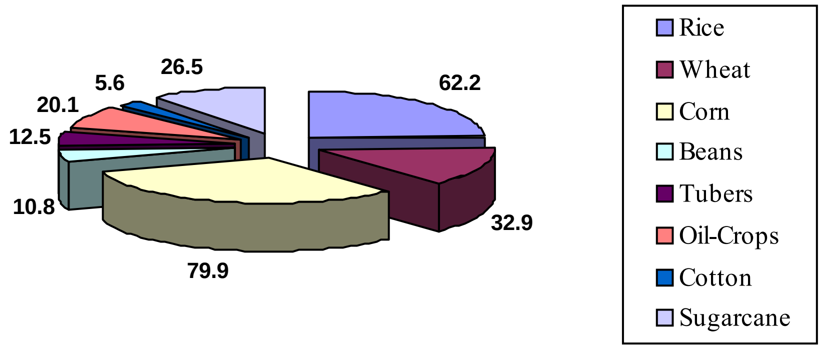

图 2　各类农业废弃物产量及能源潜力（百万吨油当量，2001 年）

1.2 林业废弃物

林业废弃物是另一重要的生物质资源。中国的林区主要分布在东北、西南、西北和南部丘陵地区。根据 2000 年完成的第 5 次国家森林资源调查（1994－1998），木材存量为 124.9 亿立方米，比第 4 次调查时增长了 4%。在中国，木材的消耗主要为三部分：44.2%用于制造木制品，32.1%由木材厂和农场自身消耗，其余用于生活燃料。1998 年薪柴及木材废弃物估计约 1.57 亿吨，合 0.67 亿吨油当量。

目前，中国还没有能源作物产业。据统计，全国已开垦耕地 130 万平方公里，还有 108 万平方公里未开发，而其中包含 35.4 万平方公里的可用耕地。如果利用这 35.4 万平方公里土地种植能源作物，则可年产生物质 1.77 亿吨，合 0.8 亿吨油当量。

1.3 禽畜排泄物

2000 年，中国禽畜的组成为：1.515 亿头大型动物如马、牛、驴、骡和骆驼等，4.47 亿头猪，2.9 亿头羊，52.8 亿头家禽。由此产生的排泄物总量干重达 3.2 亿吨，合 1.1 亿吨油当量。图 3 表示了禽畜排泄物变化的年增长趋势。

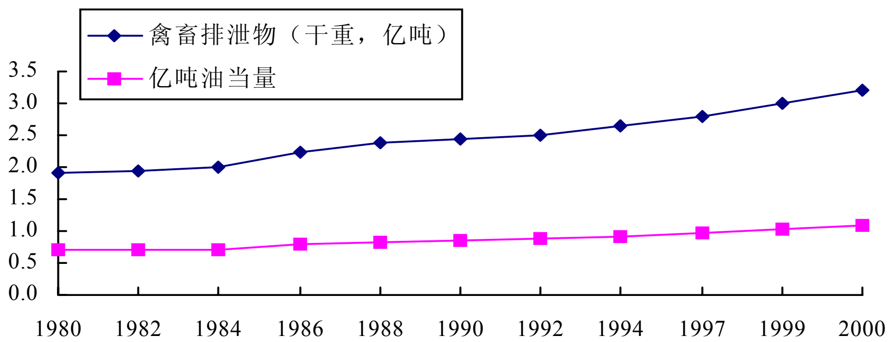

图 3 禽畜排泄物生物质能量增长趋势

1.4 城市生活垃圾

城市生活垃圾主要是由居民生活垃圾、商业和服务业垃圾、少量建筑垃圾等废弃物所构成的混合物。其成分和产量受很多因素的影响，如城市人口、居民收入、燃料结构、饮食习惯、城市建设以及季节变化等的影响。不同城市之间的垃圾成分差别很大，尤其是有机成分的含量，发达城市的垃圾有机成分高，南方城市的垃圾有机成分普遍高于北方城市。城市间生活垃圾的热值也不相同，北京、广州、上海、深圳等发达城市为 4500 kJ/kg 以上，多数地区为 3400kJ/kg 左右。中国城市生活垃圾的年产出量约 1.5 亿吨，约合 1500 万吨油当量，并以 10%左右的增长率递增。

1.5 工业废弃物

工业生物质资源是指粮食加工厂、造纸厂、木材厂、酿酒厂、糖厂和食品厂等的工业生产过程中产生的固体废弃物。据估算，中国工业固体废弃物生物质能每年可达 4800 万吨油当量。其中农作物谷壳约 1800 万吨油当量、造纸废弃物约 30 万吨油当量、木材加工废弃物约 600 万吨油当量。

二、生物质发电技术

随着我国社会经济的持续高速发展，人民生活水平的不断提高，对电力的需求逐年增长，近年来出现的电力短缺问题还没有得到彻底解决。而在农村等偏远地区，长期存在缺电少电现象。所以采用先进技术开发利用丰富的生物质能，对缓解我国能源供应压力和社会可持续发展具有长远的意义。

2.1 直接燃烧发电

生物质直接燃烧的关键技术和设备是生物质锅炉和小型蒸汽轮发电机组。我国的小型蒸汽轮机总体上技术成熟，造价低，但效率还比较低，如表 1 所示。

表 1　小型凝汽式蒸汽轮机性能

汽轮机规模（kW）	进汽参数		总进汽量（t/h）	单位耗汽量（kg/kWh）	发电效率（%）
	(MPa)	(℃)			
1500	2.35	390	8.4	5.60	20.0
3000	3.43	435	14.8	4.93	22.1
6000	3.43	435	28.5	4.75	22.9
12000	3.43	435	55.6	4.63	23.5
25000	3.43	435	111.0	4.44	24.5
25000	8.83	535	91.0	3.64	28.5

我国已有相当多的锅炉生产企业纷纷研制生产出各种类型的生物质锅炉，技

术已基本成熟，种类主要是木柴(木屑)锅炉、甘蔗渣锅炉、稻壳锅炉，而且锅炉的容量、压力参数等可根据用户的需要进行设计。木材锅炉和甘蔗渣锅炉系列品种较全，应用广泛，锅炉容量、蒸汽压力和温度范围大。但是由于国内生物质燃料供应不足，国内市场应用多为中小容量产品，大型设备主要是出口到国外生物质供应量大集中的国际市场。稻壳锅炉的容量不大，应用相对较少，主要是稻壳产生企业利用自身有限的废弃稻壳燃烧并小规模发电，缺少集中处理的大型生物质燃烧发电厂。

2.2 混合燃烧发电

由于生物质的能量密度低、体积大，运输过程增加了 CO_2的排放，不适应集中大型生物质发电厂。而分散的小型电站，投资、人工费高，效率低，经济效益差。所以在大型燃煤电厂，将生物质与矿物燃料联合燃烧成为新的概念。它不仅为生物质和矿物燃料的优化混合提供了机会，同时许多现存设备不需太大的改动，使整个投资费用低。更积极的影响是：大型电厂的可调节性大，能适应不同混合燃烧，使很燃装置能适应当地生物质的特点。

大多数燃煤电厂燃烧粉煤，生物质必须经过预处理，因为磨煤机不适合粉碎树皮、森林残余物或木块等生物质。生物质与煤炭的混合燃烧具有很大的潜力。这项技术十分简单，并且可以迅速减少二氧化碳的排放量。生物质混合燃烧可有以下四种方式：

a） 生物质在一个独立系统中燃烧，产生的热用于现有电厂的锅炉；

b） 生物质在组装于燃煤锅炉炉膛中的炉排上燃烧；

c） 用专用粉碎机粉碎生物质，在燃煤锅炉中与粉煤一起燃烧；

d） 生物质在气化炉中气化，燃气作为锅炉燃料。

虽然生物质混合燃烧发电技术有很好的经济性，但是由于在管理中缺乏有效的操作办法和监管手段，没有具体的补贴或保护政策，所以目前在我国应用很少。

2.3 气化发电

中国有良好的生物质气化发电基础，早在 20 世纪 60 年代初就开展了该方面的工作。在原来谷壳气化发电技术的基础上，对生物质气化发电技术作了进一步的研究，主要对发电容量大小和不同生物质原料进行了探索，先后完成了 2.5kW 到 200kW 的各种机组的研制。中国近几年特别重视中小型生物质气化发电技术的研究和应用，开发的中小规模生物质气化发电技术具有投资少，灵活性好等特点。研制并应用的中小型生物质气化发电系统规模已从几 kW 到 6MW，气化炉结构有层式下吸式气化炉、开心式气化炉、下吸式气化炉和循环流化床气化炉四种，采用单燃料气体内燃机和双燃料内燃机，实用的单机功率达 400kW。MW 级的气化发电系统已从单一的燃气内燃机发电发展为独特的燃气-蒸汽联合循环发电，系统

发电效率由 18%提高到 28%。循环流化床气化发电系统对于处理大规模生物值具有显著的经济效益，在我国推广很快，已成为世界上应用最多的中型生物质气化发电系统。

生物质 IGCC 作为先进的生物质气化发电技术，能耗比常规系统低，总体效率可>40%，从 1990 年起引起了极大的兴趣。目前国际上有很多发达国家开展这方面研究，主要的应用仍停留在示范和研究阶段。

2.4 各种技术应用条件

生物质直接燃烧发电技术在大规模下效率较高，单位投资也较合理。但它要求生物质集中，数量巨大，如果考虑生物质大规模收集或运输，成本较高，适于现代化大农场或大型加工厂的废物处理等，对生物质较分散的发展中国家不适合。

中小型生物质气化发电技术在发达国家已经成熟，但由于规模小，过程复杂，在发达国家没有竞争力；而其造价（1200 美元/kW 以上）和运行成本都较高，在发展中国家也很难进入市场。但中国开发的中小规模生物质气化发电技术具有投资少，发电成本较低，灵活性好的特点，是同类技术中最具竞争力的技术之一。小规模的生物质气化发电已进入商业示范阶段，适合生物质的分散利用，比较符合发展中国家的情况。

表 2　生物质发电技术特征比较

发电方式	直接燃烧	气化燃烧	直接混燃	气化混燃
技术特点	利用锅炉直接燃烧后产生蒸气发电；	气化后利用燃气轮机或内燃机发电；	生物质与煤直接混合后在锅炉里燃烧；	生物质气化后与煤在锅炉中一起燃烧；
主要优点	技术成熟、规模较大、原料预处理简单、设备较可靠、运行成本较低；	污染排放较低、 小规模效率较高、规模灵活、投资较少；	技术简单、使用方便；不改造设备情况下投资最省；	通用性较好、对原燃煤系统影响很少；经济效益较明显；
主要缺点	污染排放较高、小规模小效率太低、原料较单一、投资较大；	设备较复杂、大规模的发电系统仍未成熟、设备维护成本较高；	生物质与处理要求较严、对原系统有些影响；	增加气化设备、管理较复杂；有一定的金属腐蚀问题；
应用条件	大型发电系统（>20MW）；	中小型发电系统；	木材类原料、特种锅炉；	要求处理大量生物质的发电系统；

2.5 生物质发电技术的经济分析

2.5.1 生物质发电技术经济指标

表 3 各种生物质发电技术经济指标

指　标	生物质发电技术路线			
装机容量（MW）	24MW	6 MW	6 MW	3 MW
发电方式	进口直燃	国产直燃	高效气化	简单气化
发电效率(%)	25.6	19.5	25.6	18.0
运行时间（小时/年）	7500	6500	6500	6000
自耗电(kW)	2400	600	600	150
发电量（千度/年）	180000	39000	39000	18000
生物质耗量（kg/度）	1.05	1.37	1.05	1.48
原料价（元/吨）	171	155	155	155
消耗品成本（元/度）	0.0265	0.0265	0.045	0.05
售电量（千度/年）	162000	35100	35100	17100
工厂定员（人）	150	60	60	35
人工开支（元/人.年）	25000	25000	25000	25000
设备维护率（%）	1.5	1.5	1.5	1.5
自有资金投入（千元）	92400	13650	13650	4725
贷款资金（千元）	171600	25350	25350	8775
理论上网电价（元/度）	0.600	0.574	0.535	0.551

说明：1、原料价分别按收集范围 15 公里内 155 元/吨和 15 公里外 171 元/吨计算；
2、项目自有资金统一按 35%计，其他为利息 5%的贷款；
3、理论上网电价按总投资内部收益率 10%计算。

2.5.2 不同条件对生物质发电经济性的影响

图 4 至图 7 是原料成本等不同条件对生物质发电的经济性影响。

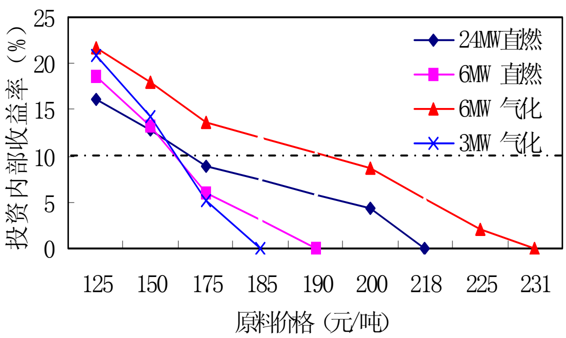

图 4 原料价格与投资内部收益率的关系

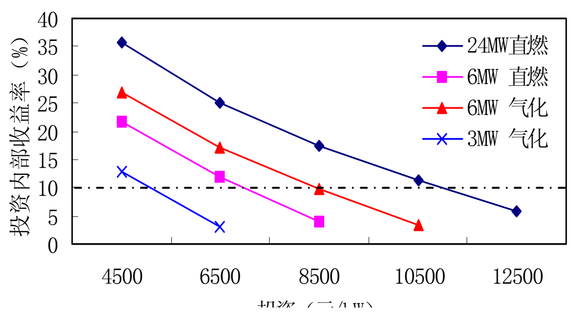

图 5 单位投资成本对投资内部收益率的影响

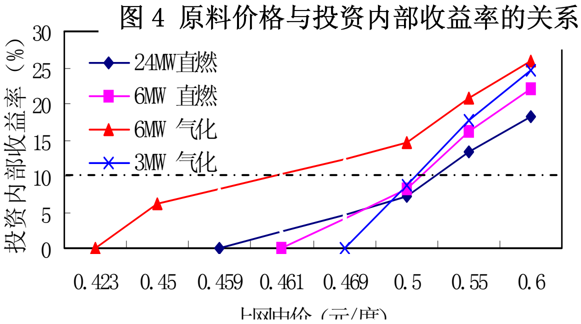

图 6 上网电价对投资内部收益率的影响

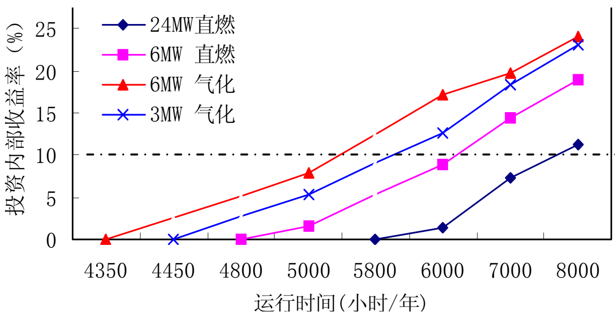

图 7 项目开工率与投资内部收益率的关系

系统发电效率高低对原料价格的变化非常敏感（图 4），效率较高的发电设备可以使用成本较高的原料。但总的来说，在上网电价为 0.52 元/吨的情况下，要保证项目的投资资金内部收益率 10%左右，其原料价格必须控制在 175 元/吨左右，这种情况在目前国内大部分地区都是比较难的，特别是对于原料需要大规模收集和储存的大规模发电系统（24MW 收集范围需要 30 公里左右，储存量需要 9 万吨以上），这种价格难度更大。

设备单位投资高低是体现技术经济性和市场竞争力的主要参数之一。从图 5 可见，在同样的投资成本下，24MW 的进口设备投资内部收益率最高，但按目前的市场价格（进口设备 11000 元/kW，国产设备 6500 元/kW），即使国产设备效率比进口设备低很多，国产设备的投资内部收益率仍比国外设备高，所以其市场竞争力仍比进口设备强。

上网电价和项目的发电成本直接相关，发电成本低的项目可以接受的上网电价就可能低一些。一般来说，效率越高的技术运行成本越低；同一类技术中规模越大，运行成本越低；但特别需要注意的是，由于设备维护的要求不同，成熟技术的运行成本较低；国外设备由于配件较贵，运行成本也较高。为了保证生物质发电项目总投资的内部收益率在 10%左右，国外进口设备项目的上网电价应在 0.6 元/度左右，而气化-余热利用系统上网电价只要 0.535 元/度。但低效率的设备对电价的变化更敏感（图 6）。

项目开工率高低是项目所采用技术成熟性的一个综合反映。项目开工率越高，技术越成熟。但另一方面，项目设计开工率越高，对技术的可靠性要求越高，对原料供应稳定性要求也越高。从图 7 可见，为达到 10%左右的投资内部收益率，24MW 项目的运行时间要求 8000 小时，即项目的开工率达 91.3%。这一要求是很高的，特别对于农业秸秆，存在种类复杂、使用原料交替更换频繁、收集半径大、储存量大等特殊困难，要保证生物质供应稳定，使发电站全年开工率达 90%以上是非常困难的。

三、生物质发电技术的发展趋势

生物质发电技术未来发展趋势受生物质资源自身的特点和我国的国情限制，可能以小型化与接近终端用户、综合利用与热电联供、分布式电力系统三种方式为主。

3.1 小型化与接近终端用户

受原料来源的限制，小型化和接近终端用户是最容易实现的技术种类。象一些碾米厂，本身的稻壳量受其生产规模的约束，产量不是很大，所以，建立与稻壳产量相应规模的发电站从原料成本上是最经济的；而且，生产的电力作为碾米

厂的补充电力，直接供给碾米厂生产和生活用，省去了并网部分，减少投资，也简化了系统运行，减少运行成本，提高系统经济性。这种利用现有生物质资源量，将电站建设在接近终端用户的方式是最直接有效而且易于应用的。

以木薯和甘蔗为原料的糖厂、中小型屠宰厂和畜禽养殖场、中小型木材制品厂都是小型化与接近终端用户的潜在用户。

3.2 综合利用与热电联供

提高系统效率，是最大限度利用生物质能源的根本措施。在较大规模的生物质发电系统中，提高系统效率易于实现的方法是使用综合利用技术和热电联供技术，这样可以根据不同原料特点、不同用户需要、不同工艺路线采取多种技术结合、生产电力和生产热相结合的技术方式，使系统得到最优化，效率最高，最大限度利用生物质资源。这类技术的潜在市场是大型屠宰厂和畜禽养殖场、大型木材制品厂、农林废弃物相对集中的区域。

3.3 分布式电力系统

从电网的安全考虑，分布式电力系统被公认为是提高供电安全的最佳手段，未来的电力系统应该是由集中式与分布式系统有机结合的系统。其主要框架结构应该是由集中式发电和远距离输电骨干网、地区输配电网、以微型电网为核心的分布式系统相结合的统一体。生物质发电系统是方便的、易实现的、可再生能源分布式发电系统，它可向终端用户提供清洁、高效、可靠的电力。无论是哪一类生物质发电方式，也无论是大、中、小哪一种规模，生物质发电都可以实现分布式电力系统。

3.4 发展远景

2010 年，国际上发达国家主要把目标集中于大型生物质气化发电技术上，在推广直接燃烧的同时，发展可以进入商业应用的 IGCC 发电系统。比如美国，目前正在进行的 6MWIGCC 项目和 60MW 中热值 IGCC 项目都要求 2010 年左右完成，并进入工业示范应用，2010 年计划总装机容量达到 6.1GW，2020 年发电量达到 200TWh（1T=1012）。2030 年，生物质发电技术将完全市场化，成为主要的能源之一。

2000~2020 年，是我国生物质发电技术的开发和完善阶段，国内技术进步完善，国外技术引进吸收，多种生物质发电技术逐步进入商业应用。如生物质气化发电技术在生物质比较丰富和能源供应比较紧张和昂贵的地区可逐渐进入商业应用；而生物质直接燃烧发电在生物质集中而且工业用能需求比较大的地方可逐渐进入商业应用。

四、中国生物质发电技术的制约因素和建议

生物质发电技术在中国的应用，最重要的制约因素来自三方面，即技术因素、经济因素和政策因素。因为中国国情的特点，这些制约因素与其他国家有很大的差别。

4.1 技术上的制约因素

中国的生物质发电技术的研究较少，这主要和中国科研投入的情况及能源设备企业的自主开发能力较差有关。近十几年来，我国在生物质发电技术研究方向的投入主要是针对中小型生物质气化发电技术，而直接燃烧技术主要由锅炉企业或其他热解设备企业自主开发。目前中国除了少数的生物质气化发电系统在进入示范应用以外，其他生物质发电技术（如直接燃烧和混烧技术）实际应用的经验积累很少。所以总的特点是成熟的生物质发电技术种类少，而整体的研究开发能力较差。

4.2 经济上的制约因素

经济环境的制约是中国发展生物质发电产业化的另一个主要障碍。中国生物质发电项目具有规模小、发电成本相对较高的特点，除了需要政府经济扶持政策给予补贴之外，另外一个主要制约的经济因素是投资资金来源少，资金筹措困难。生物质发电项相对其他发电项目来说都是小项目，资金集密程度较低，大集团和规模投资商考虑到资金分散和管理困难，投资都会非常慎重。另一方面，中小型生物质发电项目的投资大都在几百、几千万元左右，这样的资金规模对目前大部分中小企业来说仍然有相当大的压力，特别对那些农业地区的企业来说，完成这样规模的投资都是相当困难的。同时，由于生物质发电项目在整个社会的认识程度较低，投资风险较大（特别没有政策支持时），银行对这些项目给予贷款暂时较困难。

4.3 政策的制约因素

中国政府目前对可再生能源有一定的政策支持，但总的来说，这些扶持政策有很多不明确的地方，对地方政府和管理部门来说操作有一定困难。尤其是中国的鼓励政策主要是指导性的，不是强制性的，体现出来的更多是政策上的支持，缺少有效的经济配套措施。例如对可再生能源电力的一些电价优惠，都是以牺牲地方电网的直接利益为代价，以前电网全部为国家所有，这方面的影响不明显。但现在很多电网已经独立核算，这些优惠直接损害了地方的经济利益。而地方电网申请国家相应补贴又非常困难，直接影响了地方发展可再生能源电力的积极性。

4.4 中国发展生物质发电技术的政策要求

目前中国可再生能源发电技术明显受到国家政策和社会接受程度的限制，这些政策和认识程度对生物质发电项目的影响尤为明显，这主要是由于生物质在大

部分人的印象中更接近于传统能源，对是否可以享受相关优惠政策在很多地方管理部门中认识不深。另一个更主要的原因是生物质发电项目大部分是小型项目，甚至相对于风能等可再生能源项目来说也非常小，按国家现的有政策，每个几百千瓦的生物质电站都必须一样完成项目审批、可行性研究审批、优惠电价审批等统一手续。这些手续相对繁琐，明显降低了社会力量投资生物质发电项目的积极性。因此，要实现生物质发电的大规模利用，就要求中国针对生物质发电技术制定具体可行的扶持政策，包括：

4.4.1 建立程序化的立项手续

在国家立法支持的大环境下，针对生物质发电项目必须制定操作性较强的立项管理办法，落实到地方政府的管理部门中，特别是必须在农业地区明确管理部门和协调部门，让大部分投资者都了解申请的要求和程序。

4.4.2 建立规范的资格认证手续

对生物质能发电技术，由于其原料差别、规模差别和技术路线差别很大，各种项目的技术指标、资金要求和投资效益差别很大，很难有简单的标准。这就要求管理部门必须有严格与明确的资格认证和准入条件，这些准入条件主要考虑的应是对环境的影响和其他社会效益，特别是对于经济性很好的气化混合燃烧发电技术来说，这些规范的认证和监管制度将有效的促进该技术的应用。而对于技术的种类，技术水平的高低和经济性的好坏主要由业主自己选择和承担，政府部门不必过多的限制和规定。

4.4.3 建立公平竞争的市场条件

生物质发电项目由于本身固有的缺点，具体的成本决定于各地的资源情况和技术的特点，发电成本将明显高于常规电力，有的地区还高于风能发电成本。但生物质发电除了具有一般可再生能源的优势外，其最大的特点是它属于农村能源，发展生物质发电有助于提高农业产出，改善农民就业和发展农村经济，所以生物质发电在中国具有特殊的意义。这就要求政府在制定可再生能源发电的鼓励政策时，必须全面认识、综合生物质能的社会效益功能和环境效益，把这些效益全部考虑进去，才能使发展生物质能发电项目有比较公平的竞争条件和市场环境。

五、结论

（1）中国的生物质资源丰富，储量巨大，发电技术应用潜力巨大，有广阔的发展前景。

（2）鉴于中国目前经济发展的特点，在相当长时间内中国生物质资源将仍以农业废弃物为主。农业废弃物具有资源分散、收集运输成本较高、随季节性变

化较大、供应不稳定等特点。

（3）生物质发电技术已比较成熟，在中国内外都有广泛的应用。其中国外应用比较成功的是直接燃烧技术，中国在气化发电方面有较好的积累。但由于中国工业制造水平较低，加上在生物质直接燃烧发电方面没有较好的经验积累，生物质发电技术设备的整体制造和生产能力严重不足，所以在今后的发展中需大力加强装备制造能力建设，以降低投资成本。

（4）生物质发电技术的经济性总体仍较差，受环境和其他条件影响较大，因此生物质发电技术的推广应用必须有国家的特殊激励政策才能得到较快的发展。

（5）综合考虑中国的经济发展现状和生物质发电技术特点，中国应在政策环境完善方面为生物质发电技术的发展创造条件，同时在实施过程中注意鼓励生物质发电技术朝技术路线多样化、投资主体多元化的方向发展。

中国生物液体燃料的发展与潜力

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一、生物液体燃料（生物燃油）是中国今后开发利用生物质能的一个主要方向

1.1 生物液体燃料产业的主要驱动因素是石油安全[1]

生物质能资源包括农作物秸秆和农业加工剩余物、薪材及林业加工剩余物、禽畜粪便、工业有机废水和废渣、城市生活垃圾和能源植物，可转换为多种终端能源如电力、气体燃料、固体燃料和液体燃料，其中受到最多关注的是生物质液体燃料（生物燃油）。世界不少国家已经开始发展生物燃油产业（包括生物燃油加工业以及其相关产业，如能源农业和能源林业），其中共同的目的在于保障石油安全。

2004 年中国石油净进口量为 1.2 亿吨，消费量为 3.1 亿吨，进口依存度达到了 38.7％；国际能源署（IEA）预测中国到 2010 年、2020 年石油进口依存度将达到 61.0％和 76.9％。石油进口量和进口依存度的迅速攀升给中国石油安全带来了日益严重的影响；中国的石油安全问题也引起了一些国家的顾虑。国产的石油和石油替代燃料能否“养活中国”呢？与资源有限的煤炭液化和国内油气资源开发等手段相比，资源可再生而且潜力巨大的生物燃油技术也受到了越来越多的关注。巴西生物燃油产业利用蔗糖发酵制取生物乙醇，2002 年消费量达到了 104 亿公升，替代率接近 40％。

美国和欧盟国家在生物燃油产业方面也有丰富的经验。不过巴西的发展背景与中国更为接近。巴西生物燃油产业（以生物乙醇工程为开端，后来又发展了生物柴油）源于 1975 年，起因主要有二：一是出于国家能源安全和经济发展的考虑，在 1973-1974 年第一次石油危机中，由于巴西 80％的燃料依赖进口，油价暴涨使巴西损失了 40 亿美元，经济也受到沉重打击；其次是为了促进国内种植业的发展和保护农民的利益，因为巴西是全球最大的甘蔗种植区。

1.2 发展生物燃油产业将带来显著的环境效益

能源农林业的大规模发展可以有效地绿化荒山荒地、减轻土壤侵蚀和水土流失。大量使用生物燃油对中国大气环境的保护和改善也有着突出的意义：与化石燃料相比，生物燃油的使用很少产生 NOx 和 SOx 等大气污染物；由于生物质 CO_2 的吸收和排放在自然界形成碳循环，其能源利用导致的 CO_2 排放远低于常规能源。

到 2050 年生物燃油开发量如果能达到 1.05 亿吨（这一数据是基于能源研究所 2005 年“中国能源中长期开发利用前景分析”研究项目的生物质能部分的情

景分析；情景分析中能源林业以生产生物柴油原料为主，能源农业以生产生物乙醇原料为主；其中 2020 年、2030 年、2050 年预计开发量为：生物乙醇 0.039、0.079、0.16 亿吨，生物柴油 0.15、0.33、0.89 亿吨），则可绿化约 3000 万公顷荒山荒地，减排约 3.1 亿吨 CO_2。

1.3 发展生物燃油产业将为中国“三农”问题的解决做出相当的贡献

建设从能源农林业到生物燃油加工业的生物燃油产业链可以成为中国解决“三农”问题的一个有力手段。

1.3.1 带动农业经济和林业经济

2020 年生物燃油开发量预计为 1900 万吨左右，初步估算可给国家和地方创产值 1000 亿元。到 2050 年生物燃油开发量如果能达到 1.05 亿吨，将创造 5000 亿元左右的年产值、吸纳 1000 万个以上的劳动力（主要是能源农林业接纳的就业），并为带动农村经济发展起到极大的作用；形成这部分生物燃油产能的初始投资（主要是产业建设投资，荒地改造和树种等费用相对较低）预计可以控制在 1.0 万亿元以内：年产值与产能投资的比值（大于 1：2）大于某些常规能源产业的比值（例如，火电的年产值与产能投资的比值约为 1：2.5）。

1.3.2 创造大量就业特别是农村地区的就业

可以吸纳 1000 万个以上的劳动力，其中主要是农村劳动力，这有利于缓解农村大量劳动力闲置的局面。

1.3.3 为中国的城镇化建设提供有力支持

一方面，中国的城镇化建设提高了人均能源需求量，特别是人均燃油需求量；另一方面，城镇化建设需要与之相伴的产业建设和就业机会的创造（一定程度上还需要增加在农村的就业机会以缓冲农村向城镇的移民浪潮）：能源农林业（和生物燃油加工业）在这两方面都可以发挥重要作用。

二、中国生物燃油发展现状与趋势

2.1 中国发展生物燃油产业已有一定的技术基础

生物燃油产业的核心技术是生物燃油技术和能源作物的选育和种植技术。自“八五计划”期间已经开始生物燃油资源与转换技术的研究开发，采用传统技术用粮食和油料作物生产醇类和油类产品，这只限于在食品与轻工产业；制取燃料作为交通能源产业建设则是在“九五计划”期间由原国家计委公布实施。能源作物的概念对中国来说是较新的，但其选育和种植技术的相关研究实际上已有数年的基础。

2.1.1 “陈化粮”制生物燃油

目前生物燃油的主要原料为“陈化粮”。严格来说，以“陈化粮”制取生物

乙醇并不能算在能源农业的范畴，因为就其主要用途而言粮食作物与能源植物有本质区别。但这也为发展生物乙醇技术积累了技术经验和产业基础，待甜高粱等能源植物资源得到发展后，即可进行原料转移。

经国务院批准，原国家计委 2001 年 4 月 17 日发布中国实施车用汽油添加燃料乙醇的决定。同时国家质量技术监督局颁布了“变性燃料乙醇”和“车用乙醇汽油”两个国家标准。国家投资 50 余亿元，批准全国建立 4 个以消化“陈化粮”为主要目标的燃料乙醇企业，目前均已投产，总生产能力 100 余万吨。粮食为燃料乙醇原料，每吨超过 3000 元，含加工费后，燃料乙醇成本超过 4000 元/吨。

国家规定 2004 年 10 月起黑龙江、吉林、辽宁、河南、安徽 5 省及湖北、山东、河北及江苏的部分地区，强制封闭使用车用乙醇汽油。到 2005 年，上述各省及其所辖市区，军队特需和国家特种储备除外，全部实现车用乙醇汽油替代其他汽油。

2.1.2 能源农业作物甜高粱和甘蔗[2]

科技部国家“863 计划”支持的“甜高粱茎秆制取燃料乙醇”项目提供的甜高粱品种，种植技术和燃料乙醇加工技术已经较为成熟。目前已经达到年产 5000 吨燃料乙醇的生产规模。国内已经在黑龙江省、内蒙古自治区、新疆维族自治区、辽宁省和山东省等地，建立了甜高粱种植、甜高粱茎秆制取燃料乙醇加工的基地。甜高粱茎秆为燃料乙醇原料，每吨收购价 2000 元，含加工费后，燃料乙醇成本低于 3500 元/吨。16 吨甜高粱茎秆（中国北方平均 4 亩耕地的产量）可以制取 1 吨燃料乙醇。废渣还可以制取 500 公斤生物柴油。甜高粱制取乙醇仅用其茎秆，甜高粱籽粒仍然作为粮食使用（不用于发酵制乙醇）。它的适应性也很好：中国 10℃以上年度有效积温 2000℃以上的地区都可以种植；同样情况下，甜高粱比其他作物抗旱、抗涝和耐盐碱。

甘蔗是中国重要的糖料作物，近几年，广西、云南、贵州等省种蔗致富对脱贫起了一定作用，但糖的消费量有限，并且由于合成甜味素的冲击，甘蔗种植面积有大幅波动；而燃料乙醇市场需求量大，所以甘蔗在中国南方地区是最有可能大量用于生产燃料乙醇的糖类原料。大致 4 亩的甘蔗产量可制取 1 吨乙醇，与甜高粱近似；蔗渣同样可制取生物柴油。

此外，亩产乙醇量高于普通甘蔗的“能源甘蔗”在澳大利亚等国已培育成功；中国在能源甘蔗方面的研究也已经起步并得到了较快的发展。

2.1.3 能源林业作物麻疯树和黄连木[3]

中国开展能源林业作物的研发已有成果，南方已建有产业。如利用菜籽油、棉籽油、乌桕油、木油、茶油等原料小规模生产生物柴油的案例。近年来，为了不与食用油和工业用油争原料而开发了麻疯树果实、黄连木籽等作原料制取生物

柴油技术，初步具备商业化发展的条件。

四川利用麻疯树果实为原料建成了设计能力 10 万吨的柴油加工厂，现年产能力为 2 万吨，并制定了企业标准。制约生物柴油发展的因素是原料价格。麻疯树果实购入 1.4 元/公斤，每吨生物柴油需麻疯树果实 3 吨多，每吨生物柴油的原料成本超过 4000 元。种植麻疯树亩产生物柴油可接近 200 公斤。

黄连木籽含油率在 30%左右。按每亩种植 40 棵、每棵产果 20 公斤计，则亩产生物柴油约 200 公斤，与麻疯树的产量接近。

麻疯树和黄连木在中国相当面积的地域都适宜栽种；随着相关科研工作的进行，完全有可能发现或培育出其他拥有相近或更高生物燃油产量的、适宜更广泛的栽种地域的能源树种（包括麻疯树和黄连木的改良树种）。

2.1.4 生物燃油产业的经济效益[2][4]

以种植生产乙醇的甜高粱为例，按照内蒙古的试点经验，与种植普通玉米相比，每亩可增收 140 元，见表 1。

表 1 种植甜高粱与玉米的效益比较

单位/元	甜高粱每亩收入	玉米每亩收入	备注
籽粒	400	500	两者种植成本相同
茎杆	240	0	玉米茎秆直接烧掉；甜高粱茎秆卖给酒精厂
合计	640	500	

种植麻疯树的收益也较高：即便按较低的亩产量 450 公斤计，每亩收益也达 630 元。

目前生物燃油的成本比化石燃油要高一些，但技术革新对降低成本的潜力是巨大的。以巴西为例，每吨乙醇的成本从开始时的 800 美元下降到目前的 300 美元。此外，由于资源有限、不可再生，化石燃油的价格始终会上涨，生物燃油相比之下将有更强的价格竞争力。

2.2 中国生物燃油加工业目前的规模和产品价格

中国生物柴油产业刚刚起步，目前的年产量不到 3 万吨；但发展势头较好，参见表 2、表 3、表 4（资料来源：刘德顺教授，清华大学化工系）。

表 2 中国生物柴油的产业化现状

企业名称	投产时间	生产能力	实际生产规模	所用原料	工艺	生产成本	产品销售
龙岩卓越新能源有限公司	2001 年 11 月	2 万吨	2 万吨	废油、地沟油（来自全国各地）	自己研发出的固体酸催化工艺）	加工成本 800RMB/吨（不包括油脂原料）	售价 4250RMB/吨；售给当地加油站或直接面向消费者
四川古杉油脂化学有限公司	2000 年	1 万吨	<5000 吨	废油	化学碱催化	未公布	不详
海南正和有限公司	2000 年	1 万吨	不详	木本油料作物	化学碱催化	并无产品销售	—

表 3 已完成的中试情况

企业名称	投产时间	生产能力	实际生产规模	所用原料	工艺	生产成本
湖南海纳百川生物工程公司	2004-2005	200 公斤/天	200 公斤/天	菜籽油	清华大学化工系生物酶法工艺	加工成本：700-800RMB/吨（不包括油脂原料）

表 4 部分近期拟投产的产业化项目

企业名称	投产时间	生产能力	所用原料	工艺	生产成本	产品销售
河南信阳宏昌集团有限公司	2006 年	2006 年投产 3 万吨；2010 年，10 万吨；2015 年 30 万吨	当地木本油料（乌桕子油、全国各种废油）等	清华大学化工系生物酶法工艺	加工成本 700-800RMB/吨（不包括油脂原料）	全国加油站，或直接面向消费者
湖南海纳百川生物工程公司	2006 年	1 万吨	废油	清华大学化工系生物酶法工艺	加工成本：700-800RMB/吨（不包括油脂原料）	加油站；当地公交车

2005 年 4 月 1 日，安徽成为继黑龙江、吉林、辽宁、河南之后的第五个推广试用乙醇汽油的省份，中国燃料乙醇生产能力达到 82 万吨/年，如表 5。安徽丰原集团正在建设 20 万吨/年燃料乙醇装置，年内即可投产，届时中国的燃料乙醇产量将达到 102 万吨/年。燃料乙醇价格按汽油出厂价格的 0.911 与销售单位（石化厂或加油站）结算，亏损部分由国家补贴。

表 5 中国燃料乙醇生产原料和厂家分布

	产量（万吨/年）	原料	原料量（万吨/年）
吉林	30	玉米	99
黑龙江	10	玉米	33
河南	30	小麦/木薯	90
安徽	12	玉米	36

2.3 中国生物燃油产业的发展潜力与前景

2.3.1 中国具有发展生物燃油产业的巨大空间[5][6][7]

中国发展生物燃油的资源潜力主要取决于用作种植能源植物的土地资源面积和单位面积产量。

能源农业可利用的土地资源有：947 万公顷的宜耕土地后备资源，按 60％的垦殖率计入；2003 年有 72.24 万公顷的高梁种植面积，按 80％的甜高粱推广率计入；在全国 800 万公顷盐碱化耕地中，用中国已开发成功的技术加以改造的面积约为 167 万公顷，按 80％的利用率计入。总计 759.6 万公顷土地可用于能源农业。按种植甜高粱计（种植普通甘蔗的生物燃油亩产量与之接近），则可生产生物乙醇约 2850 万吨，生物柴油 1425 万吨。以上部分所利用的土地与规划中的农业用地并无多大冲突。比如说，按照粮食生产中长期预测，粮食部门所需的耕地面积并无增加，因为提高单产的潜力足以满足中国粮食需求的增加。

与上述能源农业用地无重复计算，能源林业可利用的土地资源有：林业用地中 5700 万公顷的无林地面积（部分用于发展用材林等），按 60％计入；1470 万公顷的退耕还林地，按 80％计入（现有退耕还林地相当部分用作果园，但考虑到水果的市场需求有限，而且中国尚有 212 万公顷的宜园土地后备资源，故考虑了较高的百分比）；5393 万公顷的宜林荒山荒地，按 40％计入。总计 6753 万公顷土地可用于能源林业。按种植黄连木计（种植麻疯树的生物柴油亩产量略低一些），则可生产生物柴油 20260 万吨。根据中国林业发展的中长期规划，以上划归能源林业用地的土地与规划中的林业用地的冲突性较小。

能源植物资源能有这样的潜力，一方面是要适当利用中国现有农林业用地和宜耕土地后备资源（0.552 亿公顷，约占耕地和林业用地总面积的 14％），一方面是合理开发中国的宜林荒山荒地（0.216 亿公顷，占宜林荒山荒地面积的 40％），再者是利用一定的易改造的盐碱化耕地（0.013 亿公顷，约占盐碱化耕地面积的 17％）：三部分面积合 0.78 亿公顷（与之相比，中国现有耕地 1.3 亿公顷，林业用地 2.6 亿公顷）。这些土地资源可为中国未来的本土替代燃油开发提供坚实的原料来源。

此外，技术研发还将开拓新的资源空间。工程藻类的生物量巨大，一旦高产

油藻开发成功并实现产业化，由藻类制生物柴油的规模可以达到数千万吨，因为中国有 5000 万亩可开垦的海岸滩涂和和大量的内陆水域。美国可再生能源国家实验室运用基因工程等现代生物技术，已经开发出含油超过 60％的工程微藻，每亩可生产 2 吨以上生物柴油。青岛海洋大学十几年来承担了 30 多项国家及省部级海藻育苗育种生物技术研究，拥有一批淡水和海水藻类种质资源，积累了丰富的海洋藻类研究开发经验。如果能将现代生物技术和传统育种技术相结合、优化育种条件，就有可能实现大规模养殖高产油藻。

2.3.2 中国生物燃油实际开发量的预测

上文从资源潜力的角度分析了生物燃油的潜力，但它的实际开发利用率依赖于多种复杂因素，主要如下：

（1）需求。中国未来的燃油供给是相当紧张的，本国生产、国际进口和煤炭液化所能供给的燃油都是有限的，这就为生物燃油的发展提供了良机。

（2）经济性。生物燃油的经济性主要取决于自身的技术成熟度、规模化发展所导致的成本下降、石油价格（目前还较少考虑环境成本的内部化）。石油价格在短期内的波动性和不确定性较大，但长期看来，上升趋势相当明显，与之相比，随着技术的成熟和规模的提高，生物燃油的成本将不断降低，因此竞争力会不断提高。

（3）综合性。生物燃油工程一方面其核心技术的研发相当部分是在能源技术研究部分，一方面从特点上看也是典型的能源工程，它具有规模性，也具有时间性（所以需要能源规划）：如果是利用盐碱地、荒地改造，则存在改造期的问题，特别是能源林业还存在一个能源林从栽种到成林的生长期的问题。而从生物燃油的原料来源来看，则属于农林业范畴。中国能否顺利、协调发展生物燃油，有赖于能否把能源机构、部门和农林业部门的力量成功地整合起来。以美国为例，它在能源部和农业部下都设有能源农业项目，并且彼此之间建立了很好的沟通和协作。

（4）政策性。一方面，生物燃油产业具有显著的能源、环境和社会效益，应当得到政策支持；另一方面，国家对土地使用的规划性非常强，需要在土地规划中为能源农林业的发展提供空间。

基于对以上四方面的分析，2010 年、2020 年生物燃油开发量的一种情景是：2010 年，年生产生物燃油 600 万吨，创年产值 240 亿元，其中生物乙醇（车用酒精）500 万吨、生物柴油 100 万吨；2020 年，年生产生物燃油 1900 万吨，其中生物乙醇 1000 万吨、生物柴油 900 万吨，创年产值近 1000 亿元。

三、中国生物燃油发展战略的讨论

3.1“以国家先期投入为主导，以企业、科研机构为主力”的技术研发战略[8]

技术的成熟性和经济性对新兴的可再生能源产业来说是至关重要的，不少国家在可再生能源技术研发方面都有丰富的经验，特别是美国。美国可再生能源技术发展的核心战略是一贯的、明确的：以国家先期投入为引导，吸引产业界参与研制和开发长期（20 年乃至 50 年后）可以发挥重大作用的关键技术，加速其商业化并形成相应的装备制造体系。美国政府始终重视企业占领可再生能源技术制高点的战略眼光和决心，先后制定了太阳光伏电池、风力发电装备和氢能技术发展的路线图，已经出台和即将出台一系列鼓励生物质能技术发展和商业化进程的政策法规，如“生物质研究和发展法案 2000”。

为确保生物质能研发及推广工作的开展，美国能源部计划在 4 年内投入 500 万美元研究经费，吸引相关单位对其拟定的项目进行申请。目前在美国已掀起新一轮的生物质能研发利用高潮，有大量的机构参与到该项目中。为进一步拓展科研经费来源，美国政府还推出了购买可再生能源信用卡的措施。

美国还采取了直接作用于消费者和科研人员的激励措施。例如，2003 年 7 月美国农业部（USDA）拨款 77 万美元委托美国生物柴油部（NBB）启动了生物柴油教育计划（Biodiesel Education Program)，又拨出 19 万美元用于奖励在生物柴油研发中作出了突出贡献的爱达荷大学的科研人员。

中国借鉴美国经验、强化国家先期投入的引导作用是十分重要的（特别是考虑到中国政府对能源部门、农业部门的高度控制）：关键技术的发展可以得到足够的资金；各种相互支持或相互竞争的技术可以在一个系统性的框架中得到公平的筛选和发展。

3.2 “以政策扶植为必要辅助，以市场机制为根本基础”的产业发展战略

能源农林业和生物燃油加工业是有显著的能源、社会、环境效益的产业，应当得到一定的政策支持，比如税收优惠、贴息贷款等。这对于起步中的新兴产业尤为重要。中国已出台《可再生能源法》，但和之前的《大气污染防止法》、《节约能源法》、《清洁生产促进法》等相关法律一样，在对生物质能等可再生、清洁能源的支持上基本上都属于原则性而非操作性的法律；尚待具体、明确的规章出台。此外，中国常规燃油行业尚存在相当程度的垄断，制约了生物质液体燃料产业尽快进入市场。这类问题的解决也有赖于国家政策。

美国的生物柴油产业之所以落后于欧盟，主要原因就在于它相关激励政策的滞后。2004 年底，美国总统布什签署的联邦公司税收法案中包含了对生物柴油的优惠政策，生物柴油的预期产量随之大增。

从长远来看，市场竞争机制是成本下降、竞争力提升的根本保证。参见图 1。

事实上，经济效益是对发展能源农业的最大激励。例如，2005 年 6 月 17 日，广西省百色市右江区人民政府与广西万嘉糖业公司签约，投资 5 亿元建设日榨甘蔗 5000 吨的新糖厂和年产 30 万吨燃料乙醇厂的项目。激励甘蔗生产乙醇的因素有：1、由于大型糖厂都有附属的酒精车间，增加酒精产量所需的投资远远小于普通乙醇项目（4000 元/吨乙醇产能），仅在 1000 多元/吨乙醇产能；2、含加工费后，乙醇生产成本低于 3000 元/吨，特别是再考虑到因规模效应而导致的成本下降，则利润更加可观；3、种植能源甘蔗与种植现有品种的甘蔗相比，亩产增收至少为 400 元，蔗农也有积极性；4、酒精生产的废水污染本来是一个难题，但随着治污工艺的进步，“变废为宝”，反而可以产生效益，COD_{cr}在 4 万 mg/L 以上时，四到五年内即可收回治污投资成本，之后可以盈利。

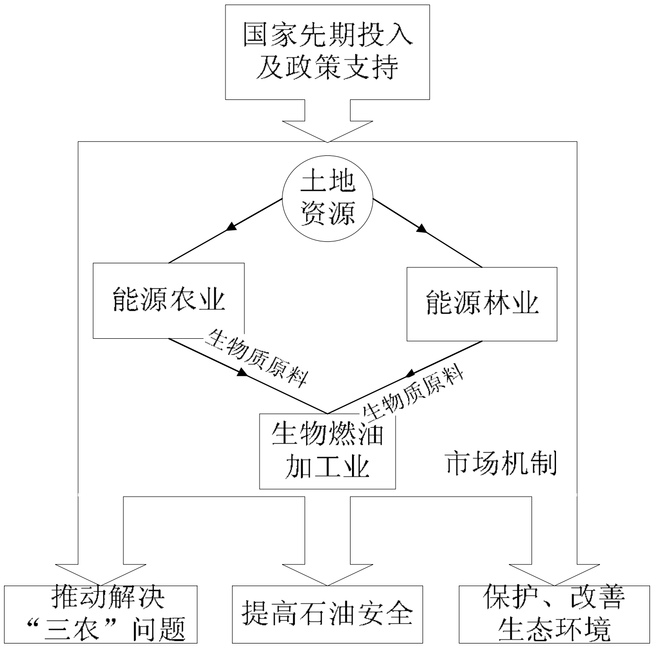

图 1 能源农林业结构和效益简图

3.3 “少占、不占粮食耕地，充分利用林地、荒地”的土地利用战略[9]

虽然中国耕地生产力还有较大提高空间，但大规模的能源农林业还是更依赖于中国面积巨大的无林地（属于林业用地）和宜林荒山荒地。事实上，中国大量的可造林地处在交通较便利并且也有充足劳动力的地区。专家认为，制约这些地区造林速度的很大原因在于制度因素（而非仅仅由于经济因素），如林木的所有权界定等。

把林业生产和能源供给结合起来的思路对带动林业发展和增加燃油供给有着重要意义。值得一提的是，印度在发展能源林业上显示了巨大的决心。印度总理称:“如果我们能启动从植物中生产生物柴油的麻疯果计划,那么就可能为 3600 万人提供就业，3300 万公顷贫瘠干旱的土地就可以开垦成油田。”

为了切实地发展中国的能源农林业，需要更进一步的基础性的调研工作（如土地资源、能源植物的地域适宜性等）并在此基础上对土地资源的利用进行合理的规划。目前，国家林业局已经开始重视能源林业的发展可能，并组织了能源林业相关的一些基础调研工作。

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中国沼气资源和开发利用

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一、我国有丰富的沼气资源

在中国，沼气的开发利用主要是通过厌氧工艺处理工农业有机废弃物、城市生活垃圾和生活污水的途径。本文研究的范围是工业有机废弃物、养殖场畜禽粪便、城市生活垃圾和废水以及农村家庭畜禽养殖等四个方面。

1.1 工业有机废水年排放量超过 25 亿吨，废渣 0.7 亿吨（2002 年）

工业有机废弃物来自于轻工企业和非轻工企业两个方面。轻工产品主要是酒精、啤酒、黄酒、白酒、淀粉、味精、饮料和造纸等 10 多个行业。目前这些行业年排放有机废水为 8.46 亿吨，废渣 0.24 亿吨。非轻工企业排放有机废物的主要是制药、屠宰、面粉、植物油、酱油、罐头、石化和橡胶等行业。据统计，每年排放有机废水 16.74 亿吨，废渣 0.49 亿吨。

通过厌氧消化工艺对上述二项的工业有机废水（25.2 亿吨/年）和废渣（0.73 亿吨/年）进行治理，可获得沼气资源量为 106.8 亿立方米（含甲烷 56%）。

依据每立方米废水产沼气量的不同，我们可以划分为三类：第一类是每立方米废弃物产沼气 10 立方米以上，主要包括酒精、白酒、淀粉、味精、柠檬酸、造纸、机械浆；第二类为每立方米废弃物产沼气 5~10 立方米，包括酶制剂、制药、纤维板、植物油等；第三类为每立方米废弃物产沼气小于 5 立方米，包括制糖、啤酒、果汁、屠宰、糠醛等。上述第一类废水虽然占总量仅为 15%左右，但产沼气的潜力占到了 60%。

考虑到中国国民经济持续快速发展，2020 年国内生产总值总量将比 2000 年翻二番。据此预测，排放的工业有机废水总量预计将增加 1 倍。这样可转化为沼气的资源量将增加 1 倍，达到 215 亿立方米。

1.2 粪污的年排放量已达 18 亿吨

根据 2003 年中国畜牧业年鉴，对中国生猪、家禽和牛的存栏量计算，全年禽畜养殖业粪便排放量已达 18 亿吨，如果加上规模化养殖场生产的冲洗水，实际排放污水总量超过 200 亿吨。按照粪便资源产沼气的潜力估计，可产沼气总量为 700 多亿立方米。

中国目前通过处理粪便而生产沼气的分二个部分。一是规模养殖场，它通过沼气工程技术处理粪便而获得沼气。2002 年全国规模养殖场（3000 头猪以上）共 8241 家，粪便总量 4900 万吨，生产沼气的潜力有 27.2 亿立方米。另外，养

殖规模在 500-3000 头猪的小型规模养殖场的粪便量为 8500 万吨，考虑到收集和管理等因素，生产沼气潜力 12.3 亿立方米。

另一个途径产生农业养殖沼气的是在中国十分普及的户用沼气池的推广应用，一个家庭饲养 4 头猪以上，就可建一个 6-10 立方米的沼气池，每年可生产沼气 300 立方米。家庭饲养猪及禽畜总量虽然很大，沼气资源量可达 600 多亿立方米，但考虑到散养，粪便收集和技术管理等因素，户用可获得的沼气资源量估计为 150-200 亿立方米。

根据畜牧业发展规划，到 2010 年和 2020 年分别以 8%和 3-5%的速度增加，那么到 2020 年沼气资源量可增加 3 倍。其中规模化养殖场随着我国经济发展将会有更大发展，如按 5%速度考虑，规模化养殖场（含小型规模养殖场）沼气资源将达到 150-200 亿立方米，而户用沼气资源量将达到 300 亿立方米。

1.3 城市生活污水和生活垃圾

2003 年中国城市生活垃圾清运量为 1.49 亿吨，生活污水为 247 亿吨。如果生活垃圾用卫生填埋产沼气的技术占 50%，则其产气资源量为 90 亿立方米，而生活污水也有 30-40%用沼气技术处理，则可产沼气的资源量为 10 亿立方米，两项共计 100 亿立方米。

按我国城市发展规划，到 2020 年城市生活垃圾和生活污水将分别增加 1 倍以上。沼气资源总量将达到 200 亿立方米。

1.4 目前可获得的沼气资源总量为 446 亿立方米

汇总上述数据如表 1，可看出：目前我国沼气资源总量有 446 亿立方米，如果按热值当量（23.02 兆焦/立方米）折算相当于 3500 万吨标准煤，可替代煤炭（20.93 兆焦/立方米）4900 万吨。

上述各项沼气资源除户用沼气资源外都可用于发电，共有 246 亿立方米。在目前中国技术水平下，每立方米沼气可发电 1.6 千瓦时，那么可发电 394 亿千瓦时，相当于装机 656 万千瓦（按年发电 6000 小时计算）。

到 2020 年中国沼气资源总量 915 亿立方米，比 2000 年增加 1 倍，相当于 7190 万标准煤，如果能开发利用，相当于替代煤炭 1 亿吨，这是一个相当可贵的能源资源。其中除了户用沼气 300 亿立方米资源外，共计 615 亿立方米，用它来发电，可产生 1230 亿千瓦时电力（每立方米沼气产生 2 千瓦时电力），装机容量能达到 2050 万千瓦，相当于 5 个大型原子能核电站（每个电站 400 万千瓦）。

表 1　全国沼气资源汇总

生产部门	目前		2020 年	
	实物量（亿 m^3）	标煤（万 tce）	实物量（亿 m^3）	标煤（万 tce）
工业有机废弃物[1]	106	833	215	1689
农业规模养殖场[1]	40	314	200	1571
户用沼气[1]	~200[2]	1570	300	2357
城市生活垃圾和生活污水[3]	~100	786	200	1571
合计	446	3503	915	7188

资料来源：[1] 研究报告：沼气工程产业化发展国家行动计划，2003 年数据，2004 年；

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二、沼气及其技术现状与发展

2.1 沼气工程技术已经基本成熟，发酵工艺以 UASB 和 CSTR 为主

经过 20 多年的发展，中国在大中型沼气工程中的工艺技术已经基本成熟，目前所采用的工艺技术已经成功地用于各类有机废水。在现有的工业有机废弃物沼气工程中，UASB 和 CSTR 占 80%（见表 2）。各种工艺类型的技术特点见表 3。

表 2　工业有机废水沼气发酵工艺

	工艺类型	个数*	各类型所占比例/%
1	UASB	200	49.26
2	CSTR	128	31.53
3	EGSB	14	3.45
4	IC	30	7.39
5	AF	8	1.97
6	UBF	5	1.23
7	其它	21	5.15
		406	100

*2000 年数据。CSTR+UASB 归入 CSTR 中。

UASB—上流式厌氧污泥床反应器，其特点是由于培养了颗粒污泥，而使厌氧菌种不致流失，大大提高了厌氧发酵效率，不需要搅拌、运转简单、适应高或低浓度 COD 负荷、占地面积减少，因此得到大量应用（占全部工程的 49.26%）。最

大的 UASB 厌氧工程建在江苏徐州房亭酒厂，其罐群总体积达 10000 m^3。国内最大 UASB 单池体积已达 4000 m^3。

CSTR—全混合厌氧工艺适用于高悬浮物、高浓度（高温）废液，CSTR 在酒精糟液处理中得到最多应用。应用于酒精废糟液处理的最大 CSTR 厌氧发酵罐群 1999 年已在江苏太仓新太酒精公司建成并投入运转。该罐群体积已达到 13200 m^3，日处理木薯干废液近 2000 m^3，日产沼气 40000 m^3 以上。最大单体罐体积 5000 m^3 建成河南南阳酒精厂。

表 3　各种发酵工艺类型的技术特点

指标 \ 类型		普通消化池	CSTR	UASB	IC	UFB
1	有机负荷/KgCOD/M3.d	< 3.0	5.0-10.0	8.0-15.0	15-30	15-30
2	进水允许有机悬浮物含量	可高达 50g/l	可高达 50g/l	一般 <4g/l	<1.5g/l	<1.5g/l
3	COD 去除率	较低	中等	较高	较高	较高
4	水力停留时间/d	15	4-10	1-10	0.5-4	0.5-3
5	动力消耗	较大	较大	较小	小	较小
6	生产控制	较容易	较容易	较难	较难	难
7	投资	较大	中等	较小	较高	较高
8	占地	较大	中等	较小	小	小
9	生产经验	少	较多	较多	较少	较少
10	操作费	低	低	低	中等	中等

注: IC 和 UFB 都属于 EGSB 的一种形式。

近几年新型高效的 IC 和 EGSB 厌氧装置得到了较多的应用，此类装置效率高、占地面积小。特别适用于悬浮物低、浓度低的废水（如：造纸、啤酒、淀粉废水）。

2.2 沼气工程配套技术得到发展

近 10 年来，中国对应用最多的全混合发酵罐和 UASB 反应器进行了大量的标准化、系列化设计及产业化开发工作，完成了全混合厌氧发酵罐罐体和罐内喷射泵搅拌、沼气搅拌的系列设计。对 UASB 罐体结构、三相分离器、布水系统等方面，形成了矩形和圆形 UASB 反应器两大系列的标准化设计。

同时，还引进了国外的新材料和新工艺来设计和建造。如德国利浦（Lipp）公司的双折边咬口技术和 Farmetic 公司的拼装制罐技术。由于在现场拼装（或卷制）方式最终成型使工程施工周期短，比普通钢板节省材料 50%以上，而且耐

腐蚀、技术先进、性能好。目前在中国已建成数十套装置。

在沼气工程配套设备研发方面也已达到一定的技术水平，已有不同型号的产品生产销售，普遍用于各类沼气工程中。包括：

（1）固液分离机被广泛采用。为了适应综合利用或发酵工艺及后处理工艺对于分离机械的需要，近年来科技人员已研制出一些符合沼气工程特点的分离机械，如振动筛、斜板筛、旋转筛、固定床过滤筛等，加复合沉淀和挤压等机械。脱水率一般在 10%～40%。基本能满足工艺和综合利用的要求。

（2）料液输送设备质量可靠。近年来，针对沼气液料的多品种、理化性质不同的特点，先后成功研制多种输送畜禽粪便的设备，其中上海自行开发的 75ＹＥ-10 泵的效率达到 65%左右，其性能甚至比国外同类产品还好。

（3）沼气的净化、储存及输送和利用设备进一步发展。已开发出一批可行的脱硫技术，脱硫效果可达到城市煤气硫化氢 H_2S 含量的标准。沼气的储存普遍采用钢制湿式气柜。干式气柜沼气的输送除选用罗茨风机、空气压缩机、氮氢气体压缩机外，还研制出沼气专用压缩机作升压设备。输气管路的材质也已多样化，以塑代钢、以铸代钢已经在一些工程中实现。与此同时，沼气的利用设备，如燃气锅炉、大型灶具、沼气发电机组的研制也获得新的进展。

2.3 沼气工程形成了各种适宜模式

在实际建设中，根据现场条件和对发酵残留物处理利用方式和要求的不同，沼气工程可以有两大类，即生态类型和环保类型。

生态型沼气工程，即沼气工程周边的农田、鱼塘、植物塘等能够完全消纳经沼气发酵后的沼渣、沼液，使沼气工程成为生态农业园区的纽带。如为畜禽粪便沼气工程，首先要将养殖业与种植业合理配置，这样既不需要后处理的高额花费，又可促进生态农业建设。生态型沼气工程的特点是，由于后处理过程比较简单，因此投资和运行成本均较低。

环保型沼气工程适于周边环境无法消纳沼气发酵后的沼渣、沼液，必须将沼渣制成商品肥料，将沼液经后处理达标排放的情况。该模式不利于资源得到充分利用，并且工程运行费用较高。

对于农业规模养殖场的沼气工程，目前在中国发展了多种模式。一种是综合利用型，即把禽畜粪便污水全部进入厌氧处理系统，这种方式工艺简便，操作方便，工程投资少，但处理后的残液浓度高，如不进行进一步处理，容易污染周围环境。另一种是把粪便污水进行干湿分离，粪便固体直接用于生产有机肥料，粪水进入处理系统处理后的沼液可用自然生态环境消纳（生态型），也可再进行好氧处理后达标排放。

2.4 户用沼气

户用沼气系统是中国农村能源利用的一种模式，它包括原料处理、沼气池、沼气输配及残留物（沼渣及沼液）利用等几个部分。家用沼气池一般在 6-10 立方米。它的原料来自于家庭饲养猪、牛、家禽及人粪等，一般饲养 4 头猪就可满足一个沼气池的原料。每年产气约 250-400 立方米。经过我国过去几十年的摸索和发展，户用沼气池的技术已经成熟，正在逐步形成产业。

2.5 目前沼气年开发利用量为 67 亿立方米

截止到 2003 年底，全国工业有机废水共建成 600 个沼气工程，厌氧池总容积 150 万立方米，年处理有机废水约 1.5 亿吨，仅占应处理的 4%，年产沼气 10 亿立方米。这些工程主要分布在山东、四川、江苏等 18 个省市区，其中山东 105 处，占 25.9%。

根据农业部统计，到 2004 年底，全国有农业养殖场大中型沼气工程 2492 处，总池容 222.2 万立方方米，产气 0.89 亿立方米，分布在全国 24 个省市，其中福建、浙江、江西、湖南等四省均超过了 200 座。

截止 2004 年底，全国户用沼气池已有 1541 万个，年产气 55.68 亿立方米。

城市生活垃圾和城市生活污水使用厌氧系统正在全国开展试点示范。据不完全统计，全国已有上百座示范工程。

表 4 为 2004 年全国沼气开发利用情况。2004 年全国沼气开发利用量已有 66.57 亿立方米，按热值当量计算，相当于替代了 523 万吨标准煤，也就是 732 万吨原煤。

表 4　中国沼气开发利用

	2004 年			2010 年			2020 年		
	数量（个）	开发量（亿 m^3）	折标煤（万 tce）	数量（个）	开发量（亿 m^3）	折标煤（万 tce）	数量（个）	开发量（亿 m^3）	折标煤（万 tce）
工业有机废水	600[1]	10	79	2000	40	314	5000	60	472
农业养殖场	2492	0.89	7	10000	20	157	20000	40	314
户用沼气	1541 万	55.68	437	3000 万	90	707	5000 万	150	1179
城市生活垃圾和生活污水	示范试验	-	-	1000	10	79	2000	20	157
合计		66.57	523		160	1257		270	2122

说明：［1］2003 年数据

［2］折标准煤系数 0.7857

2.6 2020 年开发利用沼气 270 亿立方米

沼气开发利用首先是治理污染的环保工程，也是我国发展循环经济，资源综

合利用的工程，所提供的能源又是清洁可再生的，所以国家十分重视。2006 年 1 月 1 日将正式实施我国可再生能源法。相信在今后 15 年沼气开发利用会有一个很大发展。表 4 列出了到 2010 年和 2020 年沼气开发利用的一种发展情景。可以看到，2020 年沼气开发量将达到 270 亿立方米，是 2000 年的 4 倍之多，年增长率为 9.1%，大大超过了化石燃料（煤、油气）的增长速度，相当于 2122 万吨标准煤量，也就是约 3000 万吨原煤的数量。

三、当前发展沼气的主要困境

过去 20 多年中国沼气工程有了一定的发展，沼气技术已成熟、实用，大中型沼气工程和户用沼气都有了一定的数量；设备制造和施工企业也有了初步规模。但总体说，还不具备产业化发展的能力。从户用沼气池发展看，目前国家利用国债项目每年提供 10 亿元经费，对每一个建沼气池的农户提供几百元的补贴。所以，全国每年新建的沼气池都超过了一百万个。而大中型沼气工程还处在艰难的发展之中，其主要问题是：

3.1 沼气工程缺乏市场竞争

一个万吨规模工业酒精厂其初始投资约 1000 万元，为治理排放有机废水所建的沼气工程其初始投资要 500 万元以上。建一个万头猪场的初始投资在 200 万元，而为治理粪便污水的沼气工程需 100 万元以上。这就是说，沼气工程如果与上游企业建设同步实施，投资需要增加 50%以上。这对本来就是弱质的酒精厂、养殖企业在经济上难以承受。

表 5 列出了各类沼气工程沼气发电的单位产出成本，可以看到，多数的沼气工程其动态（贴现率为 8%）发电成本在 0.5 元/千瓦时左右，大大高于煤电的发电成本。

表 5　各类沼气工程沼气发电单位产出成本

沼气工程类型		沼气单位生产成本元/m^3		发电单位生产成本/元/kWh	
		0％[1]	8%[2]	0％[1]	8％[2]
农业	能源-环保型	0.68	1.05	0.46	0.73
	能源-生态型	0.55	0.87	0.4	0.62
	综合利用型	0.37	0.55	0.27	0.43
工业[3]	青岛酒精厂	0.23	0.32	0.22	0.30
	丰宝酒厂	0.39	0.52	0.41	0.53

说明：[1] 贴现率为零，即静态。

[2] 贴现率为 8％。

沼气工程投资大，成本高，其内部收益率低，没有盈利能力，因此，仅仅依靠沼气工程自身发展无法在燃气、电力市场上与常规能源竞争。

除了自身的原因外，沼气工程缺乏市场竞争力的另一个重要因素是沼气工程技术体系不能适应产业化发展的要求，这主要表现在：沼气技术有待进一步提高，施工和设计尚没有国家统一标准，无资质认证；一些关键设备没有专门化生产，没有形成标准化系列化；计量监测是手工操作，影响正常运营，管理水平较低等等。

3.2 在全国没有形成沼气市场

沼气工程规模小而且分散，它们所生产的燃气和电力要通过燃气公司或电网供应到消费者，将给这些能源企业带来一系列的运行、安全、符合匹配和增容的问题，而且又要用高于正常的价格收购。如果没有政策规定和支持，这些企业难以接受。

目前我国的沼气技术正在发展和完善之中，沼气及其所发电力作为产品还没有一套严格的技术产品标准和监测等认证体系和市场准入制度，因此沼气及其电力不能成为市场的正式产品，这明显地阻碍了沼气市场的建立和发展。

3.3 缺乏国家级的扶持政策

虽然中国各级政府在环保治理和推动清洁能源发展上提供和实施了不少鼓励性政策支持，但只是局部性的，针对一些具体项目的，没有形成包括沼气在内的可再生能源发展的完整的政策体系。在投资补贴、燃气和电力价格、减免税收及信贷等方面都没有一个明确的激励机制。

四、克服障碍的措施和政策措施

4.1 树立沼气工程是综合性基础产业的发展观念

首先需要改变仅仅把沼气工程看作为一类能源工程或项目的观念。沼气工程治理了轻工、养殖等许多行业排放的污水，改善了环境，又提供了清洁燃料和电力，同时，使废弃物转变为高效有机肥料，资源得到了充分利用。它涉及能源、环境、资源多个领域，是一个充分利用资源实现循环经济的综合性的基础产业。

4.2 在政策扶持下沼气工程实现产业化发展

一个产业的发展必须遵循市场化发展的规律。但沼气工程由于自身的弱点，在形成和发展的初期，它必须依靠政府的政策支持。因此要有正确的沼气产业发展的思路。

（1） 目标为导向：通过国家制定有法律约束力的目标作为需求，引导市场发展。

（2） 企业是市场主体：治理环境、生产沼气和电力的主要承担者是企业，

不是政府。广大企业的参与，才能使沼气工程生产的产品形成市场，规模发展，建立产业。

（3）政府的职责：明确沼气发展的目标；提供包括价格、财政支持、税收减免、信贷等激励政策支持；培育市场，建立市场准入制度，加强技术、产品标准认证、监测、服务等体系的能力建设。

4.3 措施与政策

2006 年 1 月 1 日中国将开始实施《中华人民共和国可再生能源法》，目前中央和各级地方政府正在制订第 11 个五年计划（2006-2010 年）和 2020 年发展规划，以及《可再生能源法》的实施细则。我们相信沼气会有一个很大的发展。在具体的实施措施和政策方面，我们建议：

（1） 明确目标、市场导向

- 结合工农业有机废水治理目标，确认发展沼气在我国能源系统中的定位，制订有法律约束的发展沼气及其电力的数量目标，用需求引导市场
- 加大环保目标的执法力度，推动企业完成治理任务

（2） 企业自身努力提高市场竞争能力

- 选好技术及技术模式，扩大规模，降低成本
- 发展沼气专业化经营企业，独立经营，集中处理，降低成本

（3） 形成和规范沼气市场

- 建立和完善技术和产品标准、认证、监管和服务体系
- 建立沼气及其电力市场准入制度，电网公司必须收购沼气电力

（4） 政策扶持，让企业盈利

- 实行优惠保护性价格（电价、燃气价格）
- 建立财政专项资金

（5） 实行政策性融资

- 把沼气工程列入国家开发银行、中国农业发展银行政策性金融扶持的基本领域中，实行政策性融资
- 逐步发展成为基础设施专门化产业化发展的金融体制

（6） 公众参与

- 提高公众环保和清洁能源意识，鼓励公众积极参与和支持沼气产业发展

上述 6 条的每一条都是有针对性的，要求在沼气工程产业化发展中企业、市场、政府等各自所需要做的事情。比较起来，最为关键的，也是本研究报告特别提出的是其中的 4 点，即发展有规模的沼气专业化经营企业，电网公司必须收购电力，实行优惠价格和政策性融资。

附：

缩略语和单位符号

缩略语		单位符号	
AF	厌氧过滤器	d	天
COD	化学需氧量	kW	千瓦
CSTR	全混合式厌氧工艺	kWh	千瓦时
EGSB	厌氧颗粒污泥膨胀床	m^3	立方米
IC	厌氧内循环反应器	MJ	兆焦
IRR	内部收益率	t	吨
UASB	上流式厌氧污泥床	tce	吨标准煤
UBF	厌氧复合床		

Strategies and Policies on Promoting Massive Renewable Energy Development

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Exploitation and utilization of renewable energy are China's significant fields and ultimate approaches to establish a sustainable energy system and national development. Renewable energy technologies are national strategic fields in high-tech development, and the core technologies reflect the integrated competence of nation. Promoting greatly the exploitation and utilization of renewable energy and possessing of core technologies with owned intellectual property must take precedence in national medium-long term energy strategy and science & technology planning.

Different definitions of the range of renewable energy are stated in different research area. Here that mainly refers to wind power, solar energy, small hydropower (the capacity is no more than 50MW, including 50MW), biomass (not including traditional straw, firewood and organic waste combustion, etc.), geothermal energy, ocean energy and other non-fossil fuel and renewable energy directly from nature.

1. The significance of greatly developing renewable energy

1.1 Keep pace with the high-speed of the worldwide renewable development, decrease the gaps between China and developed countries, and promote the renewable energy industry and technology innovation

At present, the renewable energy technologies develop rapidly in the world. The global annual growth of wind power and solar PV power is as high as 30% in past few years. The cost of wind power plant in EU decreased by 20% in past 5 years, being competitive with general power plant and stepping into large developing stage. The solar PV power investment can decrease to $1/W, and be into business promotion phase. China has quite good base of exploitation and utilization of renewable energy. The capacity of small hydropower is 2,849 kW, 400,000 kW of wind power, and 1,000,000 kW of biomass. Solar hot water heaters were fixed by 40,000,000 m^2, ranking first in the world. Small hydropower technologies are worldwide advanced (the exploitations of hydropower in developed countries are almost over now); wind power industry is just beginning; biomass power technologies have well developed, but in contrast with advanced world-class the integrated technology and costs are less competitive. China should take the chance to develop the renewable energy technologies and industries by strides, by both our own researches and package imports.

1.2 Exploitation and utilization of renewable energy are the ultimate approaches to release bottleneck restriction of resource and the pressure from environment pollutions, and ensure sustainable energy supply and economy and society development.

China is confronted with the urgency both from the shortage of energy supply and environment pollutions. The GDP in year 2002 will quadruple the one in 2000 in China' development planning and the demand of energy will rise to 2,500-3,300 Mtce. At that time, the pressures come not only from the national resource and energy supply capacity, but also from the oil import dependence as high as over 60%. The energy supply security faces big challenges. China's energy consumption mainly depends on coal. Such pattern results in serious environment pollutions. 70%-90% of air pollutions as SO_2, NO_x and dust are from coal burning. The acid rain falls over one-third countrywide area. The economic loss of damage caused by air pollutions already reached 2%-3% of GDP. Worldwide, the global warming is mostly due to the emission of CO_2 by fossil fuel burning. The China's CO_2 emission in year 2000 was 13% of the one of the world. In 2030, it may be the biggest emission country, even more than USA. Although the developing countries can not fulfill the absolute and imperative obligation of CO_2 emission reduction, China will facing more and more pressures in the future international negotiations as long as the developed countries perform the emission reduction requirement. Exploitation and utilization of renewable energy are the crucial means to react to the climate change by technology innovation and strategy against the climate change China should map and take out.

1.3 Exploitation and utilization of renewable energy are the significant approaches to solve rural basic power and energy consumption problems.

Solving the problems of the remote rural off-grid power consumption is one target of China's a Well-off Society construction thought and policy landscape. There are 7 million households and 2.9 million people without power supply. Small-scale off-grid and consumer power systems, such as photovoltaic power system, wind-photovoltaic and wind-firewood power system, micro-hydropower and biogas project, are the efficient solution to remote rural area power supply. China has developed 33 MW of micro-wind-power, 920 kWp of small photovoltaic power and 174 MW of micro-hydropower, and succeeded in supplying 570,000 farmers power consumption. Rural passive-pattern sun space and biogas system is becoming the important means to rural households power use. There are more than 10,000,000 rural household biogas systems, producing 3,700,000,000 m^3 of methane annually, and 26,600,000 m^2 passive-pattern sun spaces. Meantime, the positive promotion of rural renewable energy integrated utilization eco-agriculture pattern, considering all the energy, environment and economy benefits, will contribute greatly to rural sustainable development. Promoting the exploitation and utilization of renewable energy have significance to economy development, environment protection and Well-off Society construction in remote rural areas.

1.4 The technology innovation in the renewable energy fields will be more crucial in the national integrated competence in the future

Renewable energy is crucial support of future sustainable energy system. According to predictions of UNDP and other international institutions, in the second half of the 21st century, the renewable energy will gradually replace the general fossil fuel energy and take the primary position. The technology innovation capability in the renewable energy fields will be the crucial part in the national integrated competence, and also safeguard of national economy, society development and security. At present, enhancing system construction of promoting renewable energy development have prominent foresighted and strategic significance. Meantime, the core solution to slow the climate change is technology innovation. Large-scale exploitation and utilization of renewable energy, reducing the CO_2 emission, are the important field to slow the climate change. And that will be a weighted drive to promote the technology innovation in energy fields in China, and offer a historic chance to develop by strides, and transit to a sustainable system.

2. The development potential of renewable energy in China

2.1 The exploitation potential of renewable energy resource is considerable

The area of China is large and the renewable energy resources are rich in variety and amounts, widespread all over the country. The annual radiant quantity of solar energy is 3,300 MJ/m^2*year- 8,400 MJ/m^2*year. Two-thirds of country area can receive over 6,000 MJ/m^2*year (200 W/ m^2), more than 2000 hours/year of sunlight (as 2,400 Btce/year). If the technology is feasible and the cost is acceptable, the exploitation and utilization of solar energy resource can be infinite. The overall reserves of onshore wind energy resource in 10 meters high above the land in China is about 3,226 GW, in which 253 GW can be exploited and utilized. The one offshore is 750 GW. Totally, there is 1,000 GW. China has large amount of hydropower resources, and hereinto 128 GW of exploitable small hydropower resource, producing 450 GkWh annually, 29.7% of exploitable hydropower resource, ranking the first in the world. The biomass resource is also considerable. Present annual output of crop straw is 0.7 Gton, and some that 50% can be used as energy is 0.35 Gton. The sound annual exploitation of firewood is 0.22 Gton. The resource potential of biogas converted from the organic industrial wastes and agricultural residues is 31 Gm^3. And the crop straw, firewood and wastes resource are increasing all the times. Besides, there will be double or more biomass resource potential in the future by planting bio-energy crops in low quality farms, and improving the breeding of self-sow bio-energy crops. China has a thousands kilometers of coastline, and variety of ocean energy resources such as tidal energy，ocean wave energy，ocean thermal energy and ocean salinity energy. According to the experts’ estimation, the exploitable and utilizable quantity is 50 GW, and the tidal energy available now is 22 GW. China has plenty of geothermal energy mainly including low and mid temperature. The recourse potential is as much as 7.9%

of the world. The total basin potential is as much as 200 Gtce. Hereinto, there are 6 GW of high temperature power and 3.3 Btce of low and mid temperature power.

2.2 The exploitation landscape of China' renewable energy is bright and wide

The conversion quantity from renewable energy resource potential to utilizable power is mainly due to the development of conversion technologies, the scale of the exploitation and the promotion of the government policy. According to the future development of renewable technologies, the improvement of market environment and the support of government policy, the exploitation landscape of China's renewable energy is bright and wide.

(1) Small hydropower is the most available resource to be largely exploited and utilized before 2020. The small hydropower capacity was 28.4 GW, and this will rise to 80 GW in 2020, as 63% of the exploitable quantity, and 100 GW in 2050, as 80% of the exploitable quantity.

(2) The wind power is qualified to develop by strides. The capacity in 2002 already reached 0.4 GW, and the target of 20 GW in 2020 (made by the State Development and Reform Commission) can entirely exceeded. And the total capacity will rise to 300 GW, as 30% of the exploitable quantity. At the appointed time, the wind power will be an important sort of renewable energy power.

(3) The solar photovoltaic power will step into the golden development period. At present, the quantity of solar photovoltaic power is much smaller than that of small hydropower and wind power. The number will rise to 1 GW in 2020. As long as the advancement of the technology, development of the scale and reduction of initial investment and electricity generation cost, the solar photovoltaic power will develop rapidly after 2020. The total capacity of hundreds of GW can be expected. Besides the solar photovoltaic power, the solar thermal utilization is also important. The solar hot water heater and sun space technologies are well used. The development of integrated solar architecture technology will bring a bright future to solar thermal power utilization. 40,000,000 m^2 of solar hot water heaters were fixed in 2002, ranking the first in the world. The number will rise to 0.3 Gm^2 as 36 Mtce in 2020 and 2 Gm^2 as 240 Mtce in 2050.

(4) Biomass energy is most potential renewable energy resources for its variety of species and conversion technologies and increasing quantity. It can convert to the thermal energy or liquid fuel besides the electricity power. The biomass power capacity was 1 MW in 2002. And this number will rise to 20 MW by the new electricity generation technologies e.g. efficient combustion of crop straw and firewood, gasification and biogas. Meantime, the total biomass utilization plans to reach 0.11 Gtce through greatly developing other using like biomass fuel, bio-diesel and residential alcohol and the 0.4 Gtce can be expected in 2050.

(5) The development of geothermal energy and ocean energy are affected by the technology and geography position, and will properly performed before 2050 with a bright landscape.

3. The strategic position of renewable energy in China's energy system

3.1 The renewable energy will be the main support of the transition to global sustainable energy system in the second half of the 21st century

Since the 1970's, the developed countries pay more and more attention to the energy security supply on account of the oil crisis. The research of renewable technology have widely stressed and developed by strides. Since the 1990's, the larger drive from developed countries' claim of reducing and slowing CO2 emission against the global climate change problems have promoted large-scale renewable energy industry developing rapidly. The development of renewable energy becomes the core measures for EU and other development countries against the global climate change. Germany and UK declared by lawmaking that the renewable energy will rise to 20% of the primary energy consumption in 2020. And EU proposal the long-term target of 50% in 2050. In the second half of the 21^{st} century, the renewable energy will gradually replace the general fossil fuel energy and take the primary position. Then the harmonious and sustainable development between energy and social economy can be expected.

3.2 The scenario analysis of China's future economy, society development and energy demand

China government has made the target of All-round Well-off society construction in 2020. The GDP of 2020 will quadruple the one of 2000, and GDP per capita will reach $3,000.

At present, China is in the first and mid phase of industrialization, the heavy chemical industry is developing rapidly, and people lead from a dress warmly and eat one's fill life to a well-off life. Hence the energy demand is sharp increasing. From the point of view in all the national researches, the energy demand quantity will rise to 2.5-3.3 Gtce in 2020, based on the situations that China takes the full advantage of energy efficiency potential, greatly promotes the measures to save energy, improves the industry structure, and optimizes the energy structure. It means big pressure to China's energy system mainly depending on coal. The environment pollution and energy supply will be confronted with a series of problems. The oil import dependence will exceed 50%, and that brings serious threaten to national energy security. Table 3.1 shows one scenario analysis of China's future economy development and energy consumption. The exploitation and utilization of renewable energy in the future certainly will be the main solution to transition to a sustainable energy system.

In the year 2050, China' GDP per capita will exceed $10,000 (at 2000 constant prices), the state ultimately achieves modernization. At the appointed time, the energy consumption will rise to about 5 Gtce. From the year 2020 to 2050, the energy consumption elasticity is about 0.35, as the class of developed countries. China will fulfill the industrialization and modernization by lower energy consumption.

Table 3.1 The reference scenario of China's future economy, energy and carbon emission

	2000	2020	2050
Population	12.62	14.27	15.61
GDP（10^9 dollars, at 2000constant prices）	1079.7	4319	17628
GDP Per Capita （$/capita，at 2000constant prices）	856	3027	11290
Primary Energy Consumption（Mtce）	1303	3000	5000
GDP Energy Intensity（kgce/dollar）	1.21	0.69	0.28
GDP Annual Growth Rate（%）		7.2	4.8
Energy Consumption Elasticity		0.59	0.35
GDP Energy Intensity Descent Rate（%）		2.8	3.0

3.3 The significance of renewable energy in the future energy system

According to the target of future development and estimation of the renewable energy technology, the scenario analysis of future energy system structure is given in Table 3.2. In the scenario analysis, the develop scales of the future renewable energy are more conservative than landscape of the renewable energy in the Chapter 2.2. The hydropower, wind power, solar energy and other renewable energy electricity generation in the table are calculated as the primary energy equivalent by current average energy consumption of electricity generation.

Until 2020, the renewable energy (not including large-scale hydropower) is as much as 8.6% of the primary energy, and will play a positive role in energy supply. Until 2050, the renewable energy proportion will rise to 21.6% (27.5%, including large-scale hydropower). The coal consumption in primary energy structure will decrease to 53.7% in 2020, and below 40% in 2050. The primary energy structure mainly depending on coal will be radically changed. The oil demand in 2020 will be 0.45 Gton, the production of crude oil will be 0.18-0.20 Gton, the import quantity will exceed 0.25 Gton, and the import dependence will be about 60%. The demand of new liquid fuel will be mainly fulfilled by liquefied coal and biofuel, or replaced by natural gas and fuel cells. The oil consumption is not expected to sharp increase. The development of natural gas is still in the youth period, and the annual production will continually increase. The number will rise to 100 Gm^3, but the demand will rise to 160-200 Gm^3. So the large-scale import will be required. From 2020 to 2050, 3% of annual growth rate is possible to keep. Until 2020, the nuclear power capacity will be available of 36 GW, and 200 GW in 2050. And other energy supplies should depend on renewable energy. From 2002 to 2050, according to the quadruple GDP and 4.8% annual growth rate, in the year 2050, China' GDP per capita will exceed $10,000 (at

2000 constant prices). At the appointed time, the energy consumption will rise to about 5 Gtce. The renewable energy will play a more and more crucial role in national energy system. The new increasing energy demand of the economy and society development will be fulfilled mainly depending on development of the renewable energy and transition to a sustainable energy system.

Until 2020, the renewable energy power capacity (including large-scale hydropower) is 31.8% of the total 1000 GW, and the energy consumption in electricity generation have a proportion of 49% of the primary energy. Until 2050, the total power capacity will exceed 2000 GW, and 52% of the primary energy consumption. In such power capacity, the renewable energy will be 32.4% (43.1%, including large-scale hydropower). The detail is showed in Table 3.3.

Table 3.2 The scenario analysis of future energy consumption structure

	2020		2050	
	Mtce	%	Mtce	%
Coal	1611	53.7	1970	39.4
Oil	643	21.4	720	14.4
Natural Gas	213	7.1	546	10.9
Nuclear	71	2.3	388	7.8
Hydropower	300	10.0	416	8.3
Small hydropower	96	3.2	120	2.4
Wind	16	0.5	205	4.1
Biomass	110	3.6	400	8.0
Solar	36	1.2	320	6.4
Others			35	0.7
Total	3,000	100.0	5,000	100.0

Table 3.3 The scenario analysis of future power capacity structure

	2020		2050	
Power	GW	%	GW	%
Coal	563	59.2	800	38.6
Natural Gas	60	6.3	180	8.7
Nuclear	36	3.8	200	9.7
Hydropower	250	23.6	320	15.5
Small hydropower	80	8.4	100	4.8
Wind	20	2.1	250	12.1
Biomass	20	2.1	200	9.7
Solar	1.0	0.1	100	4.8
Others			20.0	1.0
Total	951	100.0	2070	100.0

The renewable energy will play a more and more crucial role in national energy system. It is ultimate approaches against the urgency both from the shortage of energy resource and environment pollutions, and also the weighted support to build a sustainable energy system in the future. China should make long-term development strategy, overcome the drawbacks in system and market, and constitute efficient encourage policy to promote the large-scale renewable energy development.

4. The strategic thinking and target of renewable energy development

4.1 The strategic thinking of renewable energy development

The strategic thinking of renewable energy development can be generalized as follow the guideline of “target-leading, state-supporting, market-driving, technology innovating, enterprise-competing and public-participating”, conducted by the state strategic targets of renewable energy development, guaranteed by laws, rules, taxes and other economic encouragement policy, droved by the urgency from the bottleneck restriction of resource, environment pollutions problems, long-term sustainable energy supply requirements, national energy security and slowing climate change, focus on strengthening technology innovation, possessing key technology, reducing the cost, build perfect market system, promoting renewable technologies industrialization and advancing enterprise competence, attach importance to increasing the proportion of renewable energy power generation on grid, develop renewable energy technology industrialization by strides, meantime, take a important part in ensuring the energy and power supply in remote rural area and harmonized the energy, environment, and economy development.

The key to promote the renewable energy development is to orientate the position of state, all levels of government administration department, enterprise and public, build the market system to promote the sound development of renewable industry, and push the renewable enterprise continually innovating and well developed.

4.2 The strategic target of renewable energy development

In order to harmonize with the mid and long-term planning in energy field, the strategic target of the renewable energy development will be given as in 2020 and in 2050.

The strategic target in 2020: accelerate the development speed of small hydropower, with the power capacity of 70 GW-80 GW; accelerate the industrialization of wind power, with the power capacity of 20 GW-30 GW, and biomass electricity generation, with the power capacity of 10 GW-20 GW; strengthen the research on solar photovoltaic power and the support to demonstration project, with the power capacity of over 1 GW; the total power capacity of renewable energy quadruple the one in 2000, and exceed 120 GW; strengthen the promotion of solar thermal energy utilization and integrated solar architecture technology, with the solar hot water heater area of 0.25-0.30 Gm2; the annual production of biomass liquid fuel rise to 15 Mton; primarily build renewable energy industry and market system, and the proportion of the renewable energy reach over 10%; ensure the power and energy supply in the rural off-grid area mainly depending on renewable energy.

The strategic target in 2050: the renewable technology reach advanced world-class, form the perfect renewable energy industry and market system, form the harmonious situation of adjusting measures to local conditions, competitive and variety of energy pattern; the proportion of renewable energy (including large-scale hydropower)in primary energy reach close to 30%; the proportion of renewable energy power generation in total power generation exceed one third; prepare the solid base for the transition to a sustainable energy system mainly depending on renewable energy in the second half of the 21st century.

4.3 The key research field of the renewable energy technology

According to the strategic thinking and target of renewable energy development, here comes the conclusion of the key research field of the renewable energy technology:

(1) The wind power technology. The keys are on large capacity of MW, new wind power machine set with variable speed and screw distance, and off-shore wind field technology.

(2) The solar energy utilization technology. The key research are on advanced Solar light-heat transform material, heat collector structure components, new pattern solar cell material and groupware technology, grid connected and roof solar photovoltaic power system and integrated solar architecture technology.

(3) Biomass power and fuellization technology. The keys are biomass pyrogenation, gasification and electricity generation technology, biogas produce and electricity generation technology, fibrin bio-alcohol raw material, enzyme bio-diesel, bio-hydrogen generation and integrated urban waste utilization technology.

(4) Other renewable energy technologies, including solar hydrogen generation, new generation integrated geothermal utilization technology, independent ocean energy power generation and integrated utilization technology, integrated renewable energy utilization and complementary system and etc.

5. The policy and measures of promoting renewable energy development

5.1 Definitude the significance of the renewable energy in China’s long-term energy strategy, and enhance the integrated system constitution of promoting the renewable energy development

The rapid and sound development requires the integrated system constitution, to form the market system of the national law-making, encouragement policy, public participation, and to promote the renewable energy industry technology innovation and big shares of market. Currently, we should well understand the important strategic position of renewable energy in the construction of long-term sustainable energy system, increase the support to the renewable energy, and create the good market environment of the renewable energy industry development. Encourage the renewable energy enterprise to compete and innovate, widely absorb the social capital and human resource, and make it the new investment hot spot and economy growth zone. The national administration department should strengthen the adjustment and system planning, gradually build and improve the system constitution of promoting the renewable energy sound development.

5.2 Build and improve the market system of renewable energy development, encourage the innovation, enhance the enterprise competence, and accelerate the renewable energy industrialization development

Enterprises are the performers of the technology innovation. The key of renewable energy industrialization development is to advance the technology innovation capability and marketing competence of the renewable energy enterprises, and to build the market environment and system to promote the sound development. The success practices in developed countries indicate that compelling measures and market rules by national law-making has a crucial effect in promoting the renewable energy industrialization development. The system constitutions that are widely promoted in developed countries are quota system, power purchase law (or power price law), the competitive bidding system (or franchise system). According to the national conditions, the power price system is befitting. In the “The Renewable Energy Promotion Law” in the womb of time, such system is considered to adopt, and combined with the targets of the national renewable energy development, regulate both the prices and quantity to form the renewable energy promotion system.

5.3 Strengthen the support and government macro-regulation capability, and create the good policy environment and stage for the renewable energy industry.

China holds a positive attitude to support the renewable energy development, and there are several administration rules and regional rules. Such policy and measures greatly promoted the renewable energy development. But the integrated policy system have not formed, the support sometimes is not enough, and the capital resource and channels are either not guaranteed. The state should found the special capital on renewable energy (or public benefit fund, PBF), listed in the national general finance budget items, and build the special monetary policy financing system to support the renewable energy research and industrialization development. Meantime, the government administration department should strengthen the macro-regulation, intendance of the renewable energy market, regulate the price differences apportion system, and create the good market environment to renewable energy industry development.

5.4 Build and improve technology support and services system, guarantee the sound development of the renewable energy industry

At present, the renewable energy technologies develop rapidly. That requires the perfect technology support and services system to regulate and promote the sound development. Therefore, what we should do is to make the national and industry standards; positively support the standard institution for renewable energy equipments and production measures; build the certifications system; foster the renewable energy technology services market, support the professional renewable energy services enterprise development and also support the promotions and services of the renewable energy technologies.

5.5 Strengthen the government responsibility and the general services obligation of the power grid corporations, and promote the exploitation and utilization of renewable energy in rural area.

All levels of local governments have the obligation to guarantee the basic power and energy use in rural area, and the finance means and compelling policy are required for the power and energy supply in rural area. The exploitation and utilization of renewable energy, especially the off-grid and residential power generation system, are the important solution to the power and energy supply in remote rural area. The government should strengthen the social general services obligation of the power grid corporations as long as the capital and policy support. The power grid corporations should take the full advantage of small wind power system, small photovoltaic power system, wind-solar complementary power system, small hydropower system and other renewable energy technology off-grid power system and renewable energy household electricity generation system to supply the basic power and energy use for household off-grid. The government gives the subsidy in the investment and expenses. Meantime, positively support and promote the integrated renewable energy utilization patterns combined with the energy exploitation, environment protection and economic benefits, and make the exploitation and utilization of renewable energy the crucial solutions to Problems of China's Agriculture, Rural Areas and Farmers.

5.6 Strengthen the research and technology innovations in the renewable energy filed, and take into national mid and long term science planning as the prior field

Renewable energy technologies are national strategic fields in high-tech development, the core technology to the sustainable energy system, and also the important symbol reflecting the state integrated science strength and competence. China should follow the guideline of combination of self research and technology import, possess the core technologies, and fulfill industrialization. Currently, the key technology of the large-scale exploitation and utilization of renewable energy should be taken into national mid and long term science planning as the prior field, increase the research investment and give great support. In the process of renewable energy technology research and industrialization, dell with the relation between the long-term key target and short-term industrialization, the relation between package import and self research, the relation between the mainstream technology roadmap and innovation technology roadmap, and the relation between the research projects competition and platform building of science capability, to form and prove the science and technology innovation system in national energy field.

5.7 Strengthen the renewable energy information spread and the public awareness cultivation, and attract the wide participation in the exploitation and utilization of renewable energy

The foreign practices proved that the wide public participation and public opinion leading have crucial effects on renewable energy development. Enhance and strengthen the public awareness by the way of information spread, education, training and popularization of science and technology, encourage the public and the enterprises self-consciously purchase the renewable energy power, use the renewable energy production, and participate in the exploitation and utilization of renewable energy, attract the social investments, initiate the renewable energy generation and services enterprises, promote the renewable energy development, meantime, public intendance to government and enterprises of the planning and obligation in the exploitation and utilization of renewable energy can form the perfect system to promote the renewable energy development.

5.8 Strengthen the international cooperation, and promote the advanced renewable energy technology transfer to China

At present, the situation that the renewable energy develops rapidly worldwide be propitious to the international cooperation. The developed counties pay great attention to the China's big market. As long as strengthen the research and industrialization on the renewable energy technology at home, we should enhance the international cooperation in research field and the package technology import, positively participate in bilateral or multilateral international cooperation plan, especially technology transfer and international cooperation within the framework of "Climate Change Convention", import the capital and technology, and promote our state renewable energy technology and industry development. Meantime, positively support the home enterprises and research institutes to export the renewable energy technology and production, and enhance the international competence in China's renewable energy fields.

Status & Prospects of the Small-Scale Hydro Technologies in China

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1. The Status of the Hydro Energy Resource

1.1 The Hydro Energy Resource in China

The amount of available hydro energy resource is mainly determined by the surface flow and the water drop. China has superior natural conditions with plentiful surface flow and great water drop. In China, there are more than 5000 rivers with watershed above 1000 km^2. 20 of them are more than 1000 km long, more than 1600 of them have watershed above 1000 km^2, and 3019 of them have hydro energy over 10MW.

In China, the theoretical hydro energy potential is 676GW, and the annual generation is 281.3TWh. The exploitable hydro energy capacity is 378GW, and the annual generation is 1920TWh. Both of the theoretical and exploitable hydro energy resources in China rank the first in the World.

The area of China is roughly equal to Brazil, Russia, Canada and U.S.A., the total amount of the annual surface flow is smaller than these countries. But the hydro energy resources in China rank the first in the World. That is benefited from the stepped geographical feature of the high drop between western and eastern of China. On large area from "the world’s third pole" Qinghai-Tibet Plateau to the coastal plain which is only 50m above from the sea level, the water drop is over 4000m.

Until the October of 2004, over 100GW hydropower capacity has been installed in China, which is 26% of the exploitable hydro energy.

Table1: The Hydro Energy Resource in China

River System	Hydro Energy Potential			Hydro Energy Exploitable		
	MW	GW.h/a	Proportion (%)	Capacity (MW)	Annual Generation (GW·h/a)	Proportion (%)
All Rivers	676047.1	5922180	100	378532.4	1923304	100
Yangzi	268017.7	2347840	39.6	197243.3	1027498	53.4
Huanghe	40548.0	355200	6.0	28003.9	116991	6.1

Zhujiang	33483.7	293320	5.0	24850.2	112478	5.8
Hailuan	2944.0	25790	0.4	2134.8	5168	0.3
Huai	1446.0	12700	0.2	660.1	1894	0.1
Northeast	15306.0	134080	2.3	13707.5	43942	2.3
Southeast	20667.8	181050	3.1	13896.8	54741	2.9
Southwest	96901.5	848860	14.3	37684.1	209868	10.9
Brahmaputra & Other Tibet Rivers	159743.3	1399350	23.6	50382.3	296858	15.4
North Inland & Sinkiang	36985.5	323990	5.5	9969.4	53866	2.8

Chart 1: The hydro Resource Distributing in China

1.2 The characteristics of Small-scale hydro Resource of China

In China, the small-scale hydro is defined as the small or micro hydropower of which the capacity is no more than 50MW (including 50MW). Median and small tributary are all over the country, so the small-scale hydro resources are very abundant. According to the preliminary statistics, the small-scale hydro resource potential is 160GW, which is equal to 1300TWh annual generation. The amount of exploitable small-scale hydro resource of which capacity is less than 5kw (including 5kw) is 128MkW. Until 2004, the installed small-scale hydro capacity is 38.65MkW, which is 32% of exploitable small-scale hydro resource, 40% of all the installed hydropower capacity. The small-scale hydro has great potential for development.

The small-scale hydro resource is distributed in more than 1600 mountain counties, mainly in the central and west region. 63.6% of all the exploitable small-scale hydro resource is in the west region, 17.8% in the central region, and18.5% in the east region. In the west region, only about 9MkW small-scale hydro capacity – which is 12.1% of all exploitable – has been installed. Developing competence is on the low side, thus there is great development potential.

Table 2 and Chart 2 show the small-scale hydro resource potential and small-scale hydro resource exploitable in China.

Table 2: Exploitable Medium and Small-scale hydro Resource in China (MW)

Province	Small Hydro	Medium Hydro	Total	Province	Small Hydro	Medium Hydro	Total
Beijing	90.0	448.5	538.5	Hubei	4036.0	1592.2	5627.1
Hebei	939.3	346.0	1554.7	Hunan	4146.0	2798.2	6944.2
Shanxi	581.0	346.0	927.0	Guangdong	4166.0	2313.2	6479.2
Neimeng	387.0	1196.0	1583.0	Guangxi	2322.0	2589.0	4911.0
Liaoning	429.1	1028.9	1453.0	Hainan	397.0	286.3	683.7
Jilin	1887.9	1423.1	3311.0	Xichuan	5878.0	12786.3	18664.3
Heilongjiang	728.0	777.8	1505.8	Guizhou	2554.0	3640.5	6194.5
Jiangsu	112.0		112.0	Yunnan	10250.0	7175.8	17425.8
Zhejiang	3226.5	1172.5	4399.0	Xizang	16000.0	2348.0	18348.0
Anhui	684.5	450.5	1135	Shanxi	1569.0	1553.5	3102.0
Fujian	3594.0	2724.9	6318.9	Gansu	1089.0	2547.6	3636.6
Jiangxi	3083.3	2308.9	5332.2	Qinghai	2000.0	3214.6	5214.6
Shandong	215.0		215.0	Ningxia	23.0	55.0	78.0
Henan	1031.0	522.5	1553.5	Xinjiang	3979.0	7287.7	11226.7
				Total	71870.0	63181.3	150513

The top 6 provinces where small-scale hydro resource has been exploited most are Guangdong, Sichuan, Fujian, Yunnan, Hunan, and Zhejiang, the exploited resource amount is 4,080,000kW, 3,670,000kW, 3,620,000kW, 2,330,000kW, 2,170,000kW and 2,060,000kW respectively. In 2002 the provinces where the proportion of exploited small-scale hydro occupie the top 4 are Guangdong , Fujian , Zhejiang and Hainan, the proportion is 64% , 52% , 47% and 47% respectively.

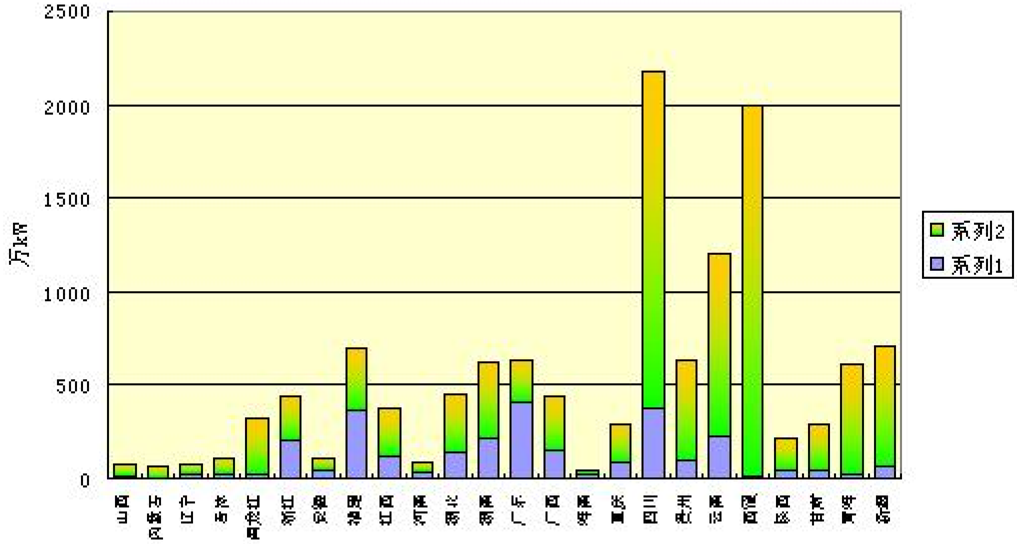

Chart 2: The Small-scale hydro Resource Potential and the Exploited Condition

2. The Present Condition of the Hydropower Technologies Development.

2.1 The Development of the Small-scale hydro Technologies and Industry in China

The small-scale hydro technologies mainly include basin plan technologies, hydro building design and construction technologies, generating sets and equipment manufacturing technologies, hydro power plant computer control technologies, power grid automatic management technologies, and power transmission and distribution computer controls technologies

Basin plan technologies are mainly for cascade exploitation of the small basin, exploitation of the leading reservoir and exploitation of the trans-basin high hydraulic head hydro power plants. Research on the whole basin is carried out to find out the scheme that has the most hydro energy resource utilization, the most electricity output, the most social benefit and the most environmental benefit. At present, the basin plan technologies for small-scale hydro have been developing rapidly, and have been spreading all over the country step by step.

The hydro building design and construction technologies are mainly for: (1) block water buildings like concrete gravity dam, stone masonry arch dam, small stone masonry multiple-arch buttress dam, concrete arch dam, rubber dam, concrete panel rock-fill dam, earth-filled dam, etc. (2) water diversion constructions for electricity generation and water diversion, trans-basin water diversion , siphon intake, etc.

Hydro building design and construction technologies are great in ratio in investments, and also restricted by the project progress. So, to develop these technologies can reduce project investment, and accelerate the construction speed effectively.
The stone masonry arch dam, especially the low-height (lower than 50m) hydropower project, is widely used in China. Compared with the same-scale stone masonry gravity dam, 1/2 ~ 1/3 of the project quantities can be saved. The stone masonry multiple-arch buttress dam, consisting of arch panel and buttresses, is suitable where river valley is wide, dam is not very high, river bank and basement of the two sides is firm enough. Compared with the same-scale stone masonry gravity dam, 30% ~ 50% of the project quantities can be saved.

Siphon intake is widely used in small-scale hydro projects. Siphon intake can cut off water flow quickly, improve the dependability of operation, reduce the operation cost, and save 20%-30% of the building construction investment. In China, the designed hydraulic head of siphon intake is 127 m, the max flow of water diversion is $14m^3/s$. The capacity of a unit is 3MW. The armored concrete pre-stressing pipeline, which can be produced as series of finished products, is also used in many small-scale hydro projects, to use armored concrete pre-stressing pipeline instead of pressure steel pipe can save more than 30% of the investment.

China has issued the sector standard of the hydraulic turbine of which capacity is under 50 MW. The bulb turbine is being popularized in low hydraulic head hydro power plants. To use the bulb turbine instead of the tubular turbine and axial flow turbine can reduce the size and the weight of the generator set, reduce factory space, increase efficiency and reduce investment. It is necessary to develop generator set with bulb turbine, vertical axle flow turbine, mix-flow turbine and impacted turbine. Assembling and testing generator set in the factory and then transporting and hoisting it wholly can guarantee the quality of the products and save installation time. Popularizing 2 fulcrums structure technologies in the design of horizontal generating set can reduce maintenance, shorten installation and adjustment time, and reduce the cost of equipment and factory building. Scientific, technological content and product quality of auxiliary equipment such as governor system and excitation device have already reached the advanced international level.

Up to now, small-scale hydro technologies have been notably improved. Equipment begins to turn from the routine to the micro type. Automatic control system enters the stage of computer digital control. Developed areas have already adopted dispatch automation system and substation automation system, some hydro power plants can realize no person operating. Also, technological transformation and power-saving technologies are widely popularized and applied. Some small-scale hydro power plants have increase efficiency by changing high-efficient runners, new excitation devices, and other advanced technologies and equipments, thus have achieved considerable economic benefits.

Optimize run and basin cascade dispatch are rapidly developed in China. Cascade dispatch computer control system for cascade hydro power plant, which adopts distributed structure and connect with automatic measure system of flood regimen survey, can automatically receive information such as rainfalls on upper reaches, water level of the reservoir and other hydrology information, thus optimize the cascade dispatch.

The power grid for small-scale hydro power plants has been developed rationally, more reliable and flexible, so it can supply more energy and better quality. The energy loss of low-voltage wire is reduced from 25% to 12% after alteration. Since "Standard of SCADA Function for Rural Hydro Power System" (SL/T 53-93) is issued, the level of automatic dispatch system for rural power grid is being steadily increased. At present, regional dispatch automation system and country-level dispatch automation system are adopted all of the country, the function reaches SCADA specification requirement, and suits for the practical standard. At the same time, substation automation control system is also popularized, 35KV and 110KV substation, which adopts computer control system, can realize no person operating.

On the basis of summarizing project experience and research production, the Ministry of Water Resources has released the technical standard of the trade, including layout, design, construct, quality, management, test, equipment for small-scale hydro power plant, which formed the standard system with China's technology features.

China has set up full industry system of small-scale hydro technology and equipment, consisting of scientific research institutions, universities and colleges, for researching, testing, and producing. Over 30 scientific research institutions, including China Institute of Water Resources and Hydropower Research, Hangzhou Rural Power Institution of Ministry of Water Resources, Electric transmission research institute of Tianjin, Tsinghua University, China Agricultural University, Huazhong University of Science & Technology etc., do the research and development of the technology and equipment for the small-scale hydro. There are over 160 small-scale hydro equipment manufacturers. Among them, over 20 large-scale equipment manufacturers such as Dongfeng Electrical Machinery, Chongqing Water Turbine Works Company Limited, Fuchunjiang Hydropower Equipment Works, mainly produce mix-flow turbine, axle flow turbine, impacted turbine generator set with unit capacity under 50000kW; Over 100 medium-scale equipment manufacturers such as Hangzhou Electric Equipment Works, Lanzhou Electric Corporation, mainly produce turbine generator set with unit capacity under 10000kW and other auxiliary equipment. The small-scale hydro equipment manufacturers' annual production capacity exceeds 2,000 MW. In the past 40 years, they have produced over 24000 small and micro turbine generator sets including over 5000 turbine generator sets with unit capacity above 500kW. Now the domestic equipments can meet the needs of the present development.

3. Development Goal and Technology Prospect for the Small-scale hydro

Industry

In China, the small-scale hydro is developed to serve local economy, especially the rural areas. It is considered as an important characteristic that the development of small-scale hydro is combined with the development of rural economy and electrification. In the past 20 years, the development of small-scale hydro was formed as the development of rural electrification in China. As the agricultural structure being upgraded and the rural economy becoming stronger, small-scale hydro has entered a new developing period, turned into a multi-objective system to meet rural electric demand, to reduce the population which cannot enjoy electricity, to alleviate poverty, to protect environment, and to replace the routine electricity, etc.

3.1 Developing policy for small-scale hydro

(1) To Meet Rural Electric Demand And To Reduce The Population Which Cannot Enjoy The Convenience Of Electricity

From the fifties of last century till now, to meet the rural electric demand and to reduce the population which cannot enjoy the convenience of electricity have always been the major aims of the small-scale hydro development. The local government, with the help of social fund-raising and people's hard working, exploits hydropower resources according to the local conditions, supplies electric power for the economy development of remote areas. 50 Years have passed, and the small-scale hydro has turned from mainly for reducing population without electricity to for improving the power consumption level. Up to now, small-scale hydro has solved over 300 million people's non-electricity problem and has provided the basic electricity for 1/2 of the territory.

The power consumption level of the remote areas of China is still on the low side at present. Especially in areas at the end of power gird or off-grid, power consumption per capita is less than 1/4 of the national countryside. There are still over 10,000,000 people without electricity living in extremely remote areas. Their power demands are few and separated, it is impossible to meet their power demands by spreading the power grid. So the development of rural electrification for reducing population without electricity is still a major aim for exploiting small-scale hydro long in the future.

(2) To raise the income of the poor population in the rural area

Statistics show that most population below the poverty line distributes in the intermediate areas between the first ladder and the second ladder. In these areas, the geographical features are mountain, hills or plateau (mountain mainly). Also, these areas are at the edge zone of the monsoon climate, suffering violent climatic changes, soil erosion and fragile ecological environment.

The economic alternative of the remote poor mountain area is limited. Outdated traditional agriculture dominates the industrial structure. Because of the lack of cultivated land, barren soil, low output of crops, there are not enough agricultural products, many families which cannot raise their incomes are under the national poverty line. People in remote poor mountain areas either have no electricity or obtain limited electric consumption. Energy for living and producing are mainly produced by biomass, manpower and animal power. The lack of electric infrastructures restricts the development of industry and the upgrading of industry structure, and that also leads to the poverty.

Exploiting small-scale hydro can promote the development of township enterprise and family workshop, increase the rural employment opportunity and raise income. Moreover, hydropower power system with about 100kW capacity, which can not only meet the power consumption demands of poor families but also provide basic electric power for producing, has positive function to dispel poverty.

(3) To protect the environment

The small-scale hydro is a type of clean and renewable energy, and it can manage and protect the ecology environment. The small-scale hydro projects combine river harnessing and power generation, by constructing a lot of water conservancy and power generation projects at the source of rivers, using biological, project managing and many other methods, increase the coverage rate of the vegetations, conserve the source of water, prevent soil erosion, and manage the small basins comprehensively. The small-scale hydro can not only improve the local ecological environment, but also protect and improve the ecological environment of midstream and downstream step by step. Small-scale hydro can also reduce the reliance on the biological fuel, prevent forest from being cut down. To use small-scale hydro instead of biological fuel is of great importance for protecting the environment, especially for reforesting formerly cultivated land, wildwood reserve, nature reserve and area with serious soil erosion.

(4) To Replace the Routine Energy

As the economy of China is growing fast, the scale of energy production and consumption is also growing rapidly. Environmental pollution by industrialization becomes more and more serious, and restricts the economy development. Because of the limited reserves, non-renewable and high environmental cost of the fossil fuel, there are potential crisis for the structure of China’s energy supply, which mainly consists of coal, petroleum, and natural gas. For the purpose of sustainable development, now the government has determined to expand the scale of the renewable energy industry instead of the routine energy. In China, the small-scale hydro resource, which is abundant and widely spread, can be the one of the best renewable energy that can replace the routine energy. If most of the small-scale hydro has been well exploited, in 2020 the capacity of small-scale hydro could be

12% of national electric power capacity. The annual output can reach 640T kWh, saving 0.2T t coal.

3.2 Developing Goal of the Small-scale hydro Power

(1) Forecast of Electric Power Demand and Supply in 2020

At the 16th Party Congress, the Party Central Committee put forward: "To build a well-off society in an all-round way. On the basis of optimized structure and increased economic returns, efforts will be made to quadruple the GDP of the year 2000, and basically accomplish industrialization by 2020." At that time, China could have huge changes on rural social economy, energy supply structure, energy styles for rural inhabitants, and electric power consumption quantity.
It is estimated that in 2020, as the agricultural production is being modernized and the average income of rural inhabitants is increasing, the energy style of rural inhabitants will be changed greatly. The use of biological fuel will decrease and the use of electric power, petroleum, and natural gas will increase. The rural structure and styles of energy consumption tend to be the same with the urban. The quantity of energy consumption will reach the average level of the developed regions'.

It is also estimated that in 2020, the energy consumption for agriculture will be 3.7% of the total amount. The average energy consumption of rural inhabitants will increase 10.6% per year, and will reach 600kWh by 2020. In 2020, rural electric consumption in China will be 590000TWh, 13.4% of all electric consumption in China, and 12.6% of rural terminal energy consumption.

Statistics show that from the end of the last 90s till the beginning of this century, China's capacity of small-scale hydro increased by 6.46% per year on average. (Table 2) In 2010 the capacity will reach 46990MW, i.e. 37% of the exploitable resources. In 2020 the capacity will reach 87710MW, i.e. 68.5% of the exploitable resources. In order to maintain the increasing speed, every year 3320 MW of small-scale hydro should be constructed.

If it can be supported by the national renewable energy law and modernized before 2015, the small-scale hydro will have the capacity of 70% exploitable resource or more with 448000TWh annual output, which is about 76% of rural electric consumption in 2020.

In 2020, small-scale hydro will still supply the electric energy for half of the territory, 1/3 of the provinces and 1/4 of the population. It will also improve the electric energy quality for agriculture and inhabitants and supply electric energy for new towns in these areas.

(2)Developing Route for the Small-scale hydro in China

The guiding ideology of developing the small-scale hydro in China is: Under the guidance of ‘science and technology as the primary productive forces’, to serve agriculture countryside and rural inhabitants, to meet the demand of hydropower for the development of rural economy and society. By modernized technologies and managements. To focus on the small-scale hydro power plants, power grid automation and information technologies, to develop technique and process management for small-scale hydro industry. To guarantee hydropower supply and quality; to improve the security reliability and efficiency; to strengthen economic potentiality and market competition ability for small-scale hydro; to provide technical support for the fast and healthy development of the small-scale hydro.

The development of technologies is following the principles below: Definite objective, uniform layout, rapid implementation, and properly in advance; advanced technologies, reliable equipment, simple and convenient control, and efficiency. To follow national technology standard strictly, first select serialized products. To select technology and equipment primarily, sometimes import overseas important technology and equipment.
The development of hydropower technologies is focusing on new materials like the synthetic material.

For low hydraulic head hydropower, development is focused on small generator set arranged diversely with shift and frequency conversion.

The powerformer may be adopted in small-scale hydro power plants in the future.

For some hydro power plants, the main parts or the whole power plants have been prefabricated with box-type small-scale hydro. The output and scale of box-type small-scale hydro will be enlarged, and the products will also be completely serialized.

Environment and security take an important part in the design of small-scale hydro.

The cost of construction and maintenance should be reduced, and the ratio of resource utilization and advance technology development should be increased.

The goal of the technology development is: before 2010, over 50% of the small-scale hydro power plants and necessary power grid should be modernized. In 2015, the small-scale hydro industry should be modernized completely. By the innovation of technique and management, the market competition ability of small-scale hydro will be improved greatly.

4. Problems and Suggestions for the Small-scale hydro

4.1 Problems of Small-scale hydro

(1) The small scale. The common problem for the renewable energy in commercial practice is: the market is comparatively narrow, and the small-scale production lends to high cost for project equipment. Low energy output results in high energy cost in producing. In fact, in developed countries small-scale hydro cannot compete with the routine energy in markets. Restricted by small economic scale, the power generation cost of small-scale hydro is higher than the routine energy.

(2) The Contradiction between high/low water level and peak/valley electricity. Most of the small-scale hydro power plants are runoff-type and lack of scheduling. On one side, generator set has to be stopped to let water pass by or the surplus electric power will be wasted on high water level or valley load period, on the other side, the shortage of power supply will happen on low water level or peak load period.

(3) The climate changes. Small-scale hydro power plants are usually designed by the average annual electricity output estimated by the conditions of hydrology and hydro-energy. Most of the data are collected before the 80s of last century. Because of the climate changes these years, the actual condition is quite different from the designation, thus affected the electricity output.

(4) The low technical and efficiency level. Some small-scale hydro power plants have been built for a long time. Most of the equipments are old with low technical and efficiency level. Statistics shows that the operating efficiency under 80% of generator sets with unit capacity between 500~3000kW is about 54% of all, the operating efficiency under 80% of generator sets with unit capacity between 3000~12000kW is about 38% of all.

(5) The improper operation. Many reservoir hydro power plants haven't do enough analysis on hydrological data, water consumption for power generating (m^3/kwh), and the relationship between hydraulic head and the number of generators. The non-optimized operation cannot improve the ability of defending flood and increase the electricity output. The improper operations are also found in runoff small-scale hydro power plants.

(6) The maintenance and malfunction. Except for regular maintenance, aged equipment causes many malfunctions, what prolongs maintenance time and decreases electricity output.

The reducing of the electricity output leads to the increase of construction cost per kW and electricity generation cost, thus the income generally cannot reach the expected sum, and the competition ability in market is weakened. In 2002, the electricity average cost of small-scale hydro power plants in China is 0.06 RMB/kWh, which is higher than the designed. A spot check about economy in 64 small-scale hydro power plants shows that the electricity average cost is 0.05RMB/kWh, higher than 0.25RMB/kWh which is the average grid-connected price.

4.2 The Problems in System, Market and Policies of Small-scale hydro

Although the technology development makes small-scale hydro more adapted in commercial field, compared with the whole level of the electric industry, there is still a long way to go. The main problems are: overall technical level of small-scale hydro is low, market development is slow, lack of research funds, and impeded technical achievement transforming channel. Other problems are shown below:

(1) The management system is unsuitable and the responsibility is unclear, which results in the low efficiency of resource arrangement and many other problems.

(2) Electricity is difficult to be exported. Because of the electricity industry monopoly and immature market, national power gird and small-scale hydro is managed by different governmental agencies. Strict limits such as output limit on high water level period for small-scale hydro power plants makes them difficult to connect with the power grid.

(3) The electrovalence is unsuitable. There are no standard policies and laws for the electricity price of the small-scale hydro. The current electricity price, which departs from the law of price, cannot reflect market demand and supply, and is not suitable for market resource arrangement and seriously limits the development of the small-scale hydro.

(4) The public welfare restriction. Some small-scale hydro power plants are attached to hydraulic projects. Besides electricity generation, they also have functions for preventing flood, irrigation and water supply. They must first prevent flood and then supply water, which leads to few or no electricity output when they are storing water or preventing flood, and extreme low water level operation when irrigating, etc.

(5) The supporting policy is limited. Policies for small-scale hydro are based on planned economy incentive policies, not on market operating. New incentive policies for small-scale hydro should be outputted quickly to correct “market distort” and “policy distort”.

If all the problems above can be solved, the annual output of small-scale hydro will be 30% higher than which is designed. Some of them will be over 50% higher.

The View on China Future Wind Power Development

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1. Wind energy resources

1.1 Wind energy reserves

Our country has a vast territory with a long coastline possessing of resourceful wind energy. According to the land data at 10 m above ground level from 900 weather stations throughout the whole country, the average wind power density is estimated at 100w/m2. The total wind energy potential amounts to about 3226 GW. The exploitable onshore wind energy potential is 253 GW while the offshore sum is 750 GW with a totally exploitable potential about 1000GW. Calculating by full load equivalent to 2000 hours per year, the annual quantity of electricity to the network from the onshore wind energy would be 500 TWh, and the offshore wind energy would provide 1800 TWh by full load equivalent to 2500 hours per year. Those quantities of electricity add up to 2300 TWh.

1.2 Wind energy distribution

Our country is a huge area with complex orographic condition. The condition and distribution of wind energy is different when the location and terrain is different. The spots with plenty wind energy mostly locate in southeast littoral areas, their nearby islands and north regions. Otherwise, there are some inland spots possessing abundant wind energy, and the offshore wind resources are rich too.

The rich zone of wind energy in north (northeast, north China, northwest) regions
The rich zone of wind energy in north (northeast, north China, and northwest) regions spreads in three northeast provinces, Heibei, Inner Mongolia, Gansu, Qinghai, Tibet, Xingjiang. This zone is almost 200 kilometers wide. The wind farms are plainness, traffic is convenient, and there is no destructive wind speed. All those regions connect into the biggest wind energy zone in China and it is easy to construct large scale wind farm. But the small capacity of local electricity network limits the scale of wind power. The regions are far from the load center, and it need transmit electricity for a long distance.

The rich zone of wind energy in southeast littoral areas and nearby islands
This zone includes areas in Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, Hainan. It is nearly 10 kilometers wide. Considering cold air in spring and winter, typhoon in summer and autumn and the channel effect of Taiwan Strait, these areas could be the best among zones of wind energy. These

littoral areas have a developed economy, and it is convenient to connect wind farms into the electricity system. Meanwhile, wind power and hydro power complement each other well in different seasons. But most of these areas have been exploited to aqua farms or shelter belt, the available land for wind turbines is too narrow.

The inland spots with abundant wind energy
Affected by lakes and special terrains, some inland spots possess abundant wind energy, such as areas near Poyang Lake in Jiangxi province, Jiugong Mountain, Lichuan region in Hubei province, etc.

The offshore zone of wind energy
In the eastern part of the country, the area of coast waters with the depth from 2 meters to 15 meters is very huge and rich in wind energy. If estimated by the same method, the offshore wind power potential will be three times that on shore at 10 m above ground level, with a number of more than 700 GW. And it is very near to the electricity load center. Thus, when the offshore wind farm technologies are practicable and economically feasible, the wind power will surely be one of the important sustainable energy resources.

2. The development of wind power

2.1 Enlarging the construction scale and normalizing management of wind farms

From the year 1986 when the first demonstration wind farm was built in Rongcheng, Shandong province, the construction scale of wind farms has been being enlarged constantly. By the end of 2004, 43 wind farms have been built, with 1292 wind turbines and a total capacity of 764 MW installed. This is the tenth in the world and the third in Asia(after India and Japan). Otherwise, the department concerned is organizing to work out the directive rules about prior period, construction, and operation of wind power. The management of wind farms becomes more and more normative.

2.2 The level of professional teams and equipment manufacturing has been increasing, and we have the qualification to develop large scale wind power.

After practice for many years, we have trained a number of professional teams for the design, development, construction, operation and management of wind power. We have basically mastered the manufacturing technologies for large scale wind turbines. The major components can be made in China. We have already some system makers for 600 KW and below wind turbines, with overall tests and small-lot manufacturing. By the end of 2004, the market share of local made wind turbines has reached 18%. The level of equipment manufacturing has been increasing continuously. We can design and make 750 KW fixed propeller pitch and rotational speed type, equal to the international level of mid 1990s. The joint-designed 1200 KW and independent-designed 1000 variable propeller pitch and rotational speed types are installed in 2005, for experimental operations.

2.3 Costs of wind power have been decreasing continuously.

With the forming and developing of wind power industry, costs of wind farm construction and operation have been decreasing by introducing technologies, accelerating the localization of wind turbines and enhancing the management of construction and operation of wind farms. The initial outlay has been decreased from about 12000 yuan/KW in 1994 to 9000 yuan/KW now; meanwhile the network price for wind power has been reduced from more than 1 yuan/KWh to 0.6 yuan/KWh.

2.4 It is regulated in The State Department Electricity Network Price Reform Plan in 2003 that wind power does not engage in market competitions temporally. The quantities of electricity should be bought by network enterprises at a certain price that is given by the government or a bid price with priority. The National Development and Reform Commission began to extend wind power concessions for exploitation in 2003. The exploitation companies and network prices for wind power are confirmed by bidding. The confirmed companies need to sign contacts with network companies for selling their wind power and ensuring all the wind power can be sent to the network. The portion of wind power price that exceeds normal energy will be allocated in the domain of provinces. This is propitious for all kinds of external and internal investors to exploit wind power.

2.5 In The China Renewable Energy LAW passed in Feb 28, 2005, it is regulated that the network price for renewable energy power project is given by state price governing department according to the characteristics of different types of renewable energy power and different regions, with the principles for promoting the exploitation and utilization of renewable energy and for the economical feasibility in reason. Connect fees cost by network companies for wind power and other reasonable correlative fees, can be counted into the costs for electricity transmit, and can be reclaimed in sales prices of electricity. The portion of fees that is used by network companies to buy renewable energy power according to the article 19, which is higher than those fees cost by purchasing normal energy power, can be allocated in sales prices for electricity. The Act makes the specialty of wind power concession projects into general rules by law, so the future development of wind power will be brought into the frame of laws.

3. Existing problems

3.1 Resources

It is necessary to begin the second wind energy census. On the basis of observing data from existing weather stations, we should assess the total amount of wind resources by recent general international criterions. Then, we can workout a high-resolution map of wind power resource distribution by adopting numerical simulation technology and estimate the amount of exploitable wind energy. The most important thing is to use GIS (geography information system) to calculate the economically exploitable reserves considering network, roads, available lands, environmental effects, layouts of development of local economics, etc.

3.2 Localization of wind power equipment manufacturing

The existing manufacturing level is far behind the market needs for technologies. The power of domestic finalized wind turbines is below the MW level. The maxim is 750 KW while most the needs of markets are MW level types. Domestic wind turbine manufacturers are facing pressures from mapping out technology route from fixed to variable propeller pitch and rotating speed, and also pressures from raising single turbine power from hundred KW level to MW level. The technology span is relatively long.

The independent research strength is too weak. For the little research funds input by the government and enterprises and lack of fundamental research accumulation and qualified personnel, our research ability on wind turbines needs to be improved. In total, we are still in the stage of tracing and introducing oversea advanced technologies. Although we have induced some licenses, a part of them are eliminated technologies, or limited by the technologies, crafts, and materials of domestic mating factories, the quality and performance of the components take some time to reach the international level, despite of the advanced design drawings. It is expensive for companies to purchase the manufacturing licenses, and advantage of the price-performance ratio of turbines is not obvious in early stages.

In the research of wind turbines, the turbine product itself has been paid much attention while the mating job has not been regarded enough. Some component jobs that should be done in labs must be done in wind farms after general assembly because of the imperfection of experiment and test methods. The test and authentication system has not been established.

The level of research and industrialization of wind turbine mating components is relatively low. This makes the whole turbine research tougher and the speed more slowly. Especially for the variable propeller pitch and rotating speed type, the research of relative components and manufacturing is still in initial stage. As for the variable propeller pitch system, low-speed magneto alternator, double-fed generator, variable-speed gear box, AC/DC alternating current converter and electric controlled system, more science and technology researches are needed.

3.3 The cost and network price of wind power is high

Basic condition initialized: according to the average level of domestic wind farms, the basic initialized conditions are that: the installed capacity of wind power is 50 MW, the annual quantities of electricity on network equal to that of running 2000 hours with full load, the construction cost is 8000-10000 yuan/KW and the depreciation period is 12.5 years. Other conditions will be set by experiences.

Financial conditions: the gross investment is decided separately as 400 million yuan (8000 yuan/KW), 450 million yuan (9000yuan/KW) and 500 million (10000yuan/KW). The circulating fund is 1.5 million yuan. The proportion of project capital is 20%. The other will be lent from domestic commercial banks. The length of loans will be 15 years. The annual interest of loans will be 6.12%. The rate of added value tax is 8.5%, and the income tax rate is 33%. The IRR will be 10%.

The calculating of wind power cost and network price:
According to the listed conditions and the network price system of wind power, aimed for a 10% IRR, the average cost for wind power is 0.373-0.461 yuan/KWh and the reasonable network price is 0.566-0.703 yuan/KWh (including added value tax), when quantities of electricity on network are equivalent full load 2000 hours and the construction cost is 8000-10000 yuan/KW. The cost is high in the early stages mostly because the return of loans and pay of interests. After loans are paid off, the average cost will be decreased to a very low level.

Construction costs affect network price obviously. When the costs increase, the network price will increase for the same ratio under the same IRR.

Our country has a vast territory. The resource conditions of wind power differ from each other in different areas. Even in the same wind farm, the distribution of wind resources may have differences. To analyze the electricity quantity variety effects for costs and network prices caused by the differences of wind power, we will calculate separately the costs and network prices below when the equivalent full load hours is 1400, 1600, 1800, 2200, 2400, 2600, 2800, 3000:

Table 1 the wind power costs under different wind resource conditions

equivalent full load hours / investment	1400	1600	1800	2000	2200	2400	2600	2800	3000
8000yuan/KW	0.533	0.466	0.414	0.373	0.339	0.311	0.287	0.266	0.249
9000yuan/KW	0.596	0.521	0.464	0.417	0.379	0.348	0.321	0.298	0.278
10000yuan/KW	0.659	0.577	0.513	0.461	0.419	0.385	0.355	0.330	0.308

Table 2 the network prices under different wind resource conditions

equivalent full load hours / investment	1400	1600	1800	2000	2200	2400	2600	2800	3000
8000yuan/KW	0.810	0.708	0.630	0.566	0.515	0.472	0.436	0.405	0.378
9000yuan/KW	0.907	0.794	0.705	0.635	0.577	0.529	0.488	0.454	0.423
10000yuan/KW	1.005	0.879	0.781	0.703	0.639	0.586	0.541	0.502	0.469

If the average level in the whole country is to invest 9000 yuan for every KW, the network price for wind power will be about 0.63 yuan/KWh, when the equivalent full load hours are 2000. This is twice that of average thermal power level as the price for thermal power is only 0.31 yuan/KWh.

3.4 The restriction of the network

While wind farms are connected to the network and provide their clean energy, they will also bring some negative effects on operations of the network. With the increase of installed capacity of wind farms and of the wind power proportion of a certain local network, these negative effects will be the restrictive factors for connecting wind power to the network.

Wind power will lower the precision of predicting the network load, and then affects the schedule and operation ways, the voltage adjustment, the current distribution, the quality of electricity, the accident level, the stability of the network, etc.

Because of wind power's connatural intermittence and wave character, the reliability of the network will decrease, and the operation cost may increase. To conquer the problems of reliability and quality, the network companies need to invest on researches and equipments. We must research and resolve those negative effects which come from connecting wind power to the network when we make great efforts to develop it.

4. The policy suggestions

1. We should enhance the work in early stages of wind power. We should establish the normal early-stage financial passes of wind power. We should arrange certain funds to measure and assess wind resources in wind farms, to meet the requirements of annual exploit plans for wind farm projects.

2. We should make detailed implement rules for China Renewable Energy Law. Exercisable and reasonable prices should be decided by the government, according to the resource conditions of every project and logical revenues for investors, meanwhile the specific operable method should be worked out for allocating the difference between wind power price and thermal power price.

3. We should accelerate the localization of wind turbines. Through the combination of trade and technology and by the principle of uniting introducing, digesting, absorbing and independently exploiting, we should master the manufacturing technologies of MW level large type wind turbines step by step. We should introduce oversea intelligence to research wind turbines that we have independent intellectual assets in the forms of copyright, and explore international markets.

4. We should establish national product detection centers, quality assurance control and authentication systems for wind power manufacturing. We should gradually improve the product quality, decrease the costs and perfect the services.

5. We should work out the network construction layout that adapts the development of wind power, and research the resolutions for the negative effects to the network from wind power.

5. The 11th five-year plan and 2020 wind power layout.

70% of our energy structure is coal-fired power. With the rapid increase of coal-fired power load, the pressures from environmental effects especially from carbon emissions reduction grow more and more. Wind power is a kind of clean renewable energy. Our country has a rich wind recourses and could exploit it in large scale. The cost of wind power has been decreasing yearly and wind power has a broad prospect. The layout aim of installed capacity of wind power is 1 GW in 2005, 4-5 GW in 2010, 20-30 GW in 2020.

From 2004-2005, in the late stage of 10th five-year plan, two wind power concession projects in Rudong, Jiangsu province and Huilai, Guangdong province will be constructed as a focal point. Experiences for large scale wind farm construction will be gained. By the end of 2005, the aim of total wind power installed capacity is 1 GW.

From 2006-2010, during the period of 11th five-year plan, newly installed capacity of wind power will be 3 GW, which means an annual speed of 600-800 MW. By the end of 2010, the accumulating installed capacity will be about 4-5 GW. Such market space is provided for domestic wind turbine manufacturers to increase their manufacture ability. National Development and Reform Commission sent out a document that demands localization of all the wind power projects reach 70%, otherwise, they could not be approved. Later, NDRC sent out another document to assist domestic wind turbine manufacturers in cooperating with power supply factories. It will provide a wind power market assurance of 500 MW and pick up the development speed of wind power manufacturing.

For the moment, the planned major projects include: 310 MW coastal and littoral demonstration project in Guangdong province, 220 MW littoral and island project in

Fujian province, 120 MW project in shanghai, 450 MW in Jiangsu province, 210 MW in Shandong province, 330 MW in Jilin province, 500 MW in Inner Mongolia, 320 MW in Heibei province, 260MW in Gansu province, 190 MW in Ninxia province, 220 MW in Xinjiang province. At present, the local governments and exploitation companies in each province are requiring a larger planned wind power capacity.

The planned aim in 2020 is 20-30GW, and wind power will possess a proportion in the power structure. It is about 2-3% of 1000 GW installed capacity, 1-1.5% of total quantities of electricity in the whole country.

After 2020, with the gradual decrease of fossil fuel resources, the cost will increase. Wind power will have the ability to compete in markets and will develop faster. After 2030, the hydro resources will all be exploited, and we will exploit offshore wind power on a large scale.

Present Situation and Prediction on Photovoltaic in China

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1. Strategic Status of Photovoltaic (PV) in China

1.1 Condition and Prediction of Energy Resources and Renewable Energy in China

No matter in the world or in China, the general energy is limited. The reserve of primary energy in China is much lower than the average level in the world, which accounts for only 10% of the total global storage volume. Figure one illustrates the reserve prediction of general energy in the world and in China.

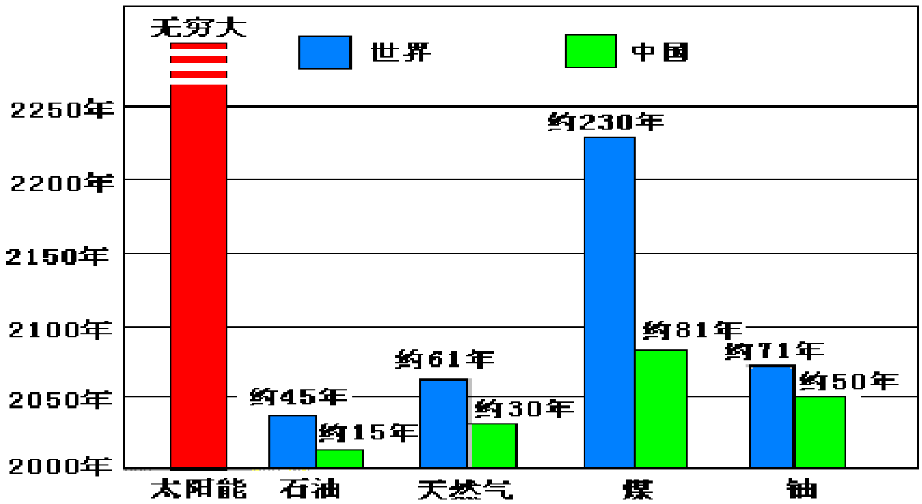


Figure 1. Reserve prediction of general energy in the World and in China

(Zhao Yunwen)

In the long-term perspective, renewable energy would be the major energy source for human beings in the future, therefore most developed countries and some developing countries are paying much attention to the importance of renewable energy to the future energy supply. In the new field of renewable energy, PV and wind power are developing so fast that most countries in the world regard the business development and utilization of PV and wind power as the main development objectives. According to the prediction of JRC in Europe, to 2030, PV will show its importance in the world electricity supply, accounting more than 10% of the total amount and the renewable energy will account for 30%. In 2050, the PV and renewable energy will reach 20% and more than 50% of the total energy consumption respectively. In the end of this century, PV will play the leading role in the energy structure.

Figure 2 illustrated the prediction of JRC.

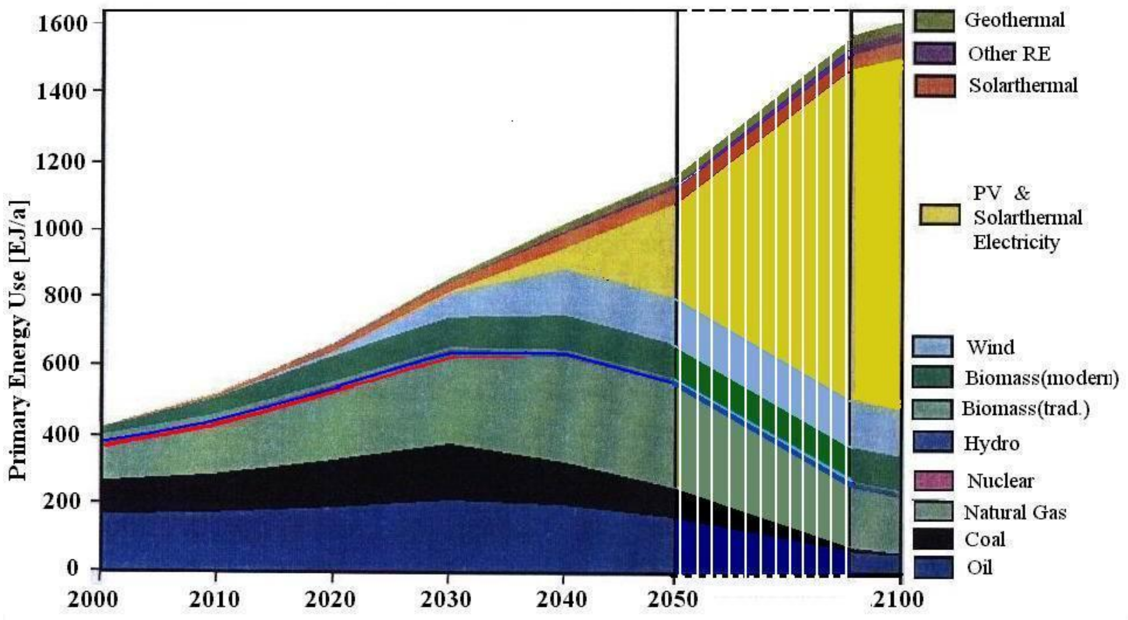


Figure 2. Development Trends of Energy in the World（PVNET2003）

China is a big country in energy production as well as in consumption. The total energy consumption in China in 2003 is 1.68 billion ton, increasing 13% compared to 2002. The consumption of coal, oil, natural gas and hydropower occupied 67.1%, 22.7%, 2.8% and 7.3% of the total amount respectively and the import of oil reached 97 million tons. Because of the powerful increasing of energy demand, the proportion of coal in the energy consumption is 1 percent higher than that in 2002. Figure 3 illustrated the composition of primary energy consumption in 2003.

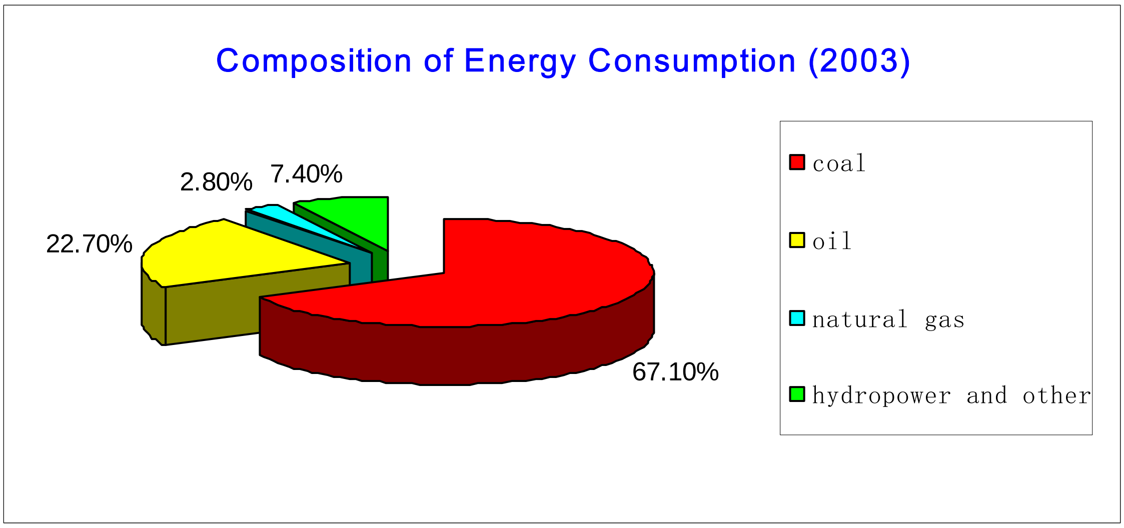


Figure 3. Composition of primary energy consumption in 2003 (Shi Lishan)

The government in China pays much attention to the development of renewable energy technologies, basically hydropower, wind power, bio-energy, solar energy, geothermal energy, ocean energy and so on. The status of the development of renewable energy in our country at present are indicated as follows.

Hydropower: The capacity of economically exploitable hydropower in our country is 390 million KW, whose annual electricity generation is 1.7 trillion KWh, including 125 million KW from small hydro power plants of 50000 KW and below. Until the end of 2003, the installed capacity of hydropower is 90 million KW, which of the small hydro power plants is 30 million KW.

Wind power: Our country locates on the verge of Pacific Ocean, where there are plenty of monsoons. The coastline extends more than 18000 km. And there are many mountains inland which change the distribution of the air pressure. All of the above made our country have widespread wind power resources. Estimated based on the wind power records in National Observatory, the capacity of exploitable wind power inland is about 250 million KW while the capacity on the sea is 750 million KW, thus the total capacity of exploitable wind power in our country is 1000 million KW. The installed capacity of wind power electricity connected to the grid is 570000 KW, besides, there are about 180000 small wind power generators in the remote area, whose total capacity is about 35000 KW.

Solar energy: The using methods are mainly thermal usage and PV usage. Till the end of 2003, the installed capacity of PV batteries is about 50000 KW, being used for electricity supply to the household, traffic and communication in remote areas. The experiments and demonstrations of connected PV electricity generation systems have already begun. There are about 10 solar PV battery power plants all over the country, whose total capacity is more than 20000 KW. Till the end of 2003, usage amount of solar water heater all over the country is 52 million M3, occupying 40% of the global volume of use, and the annual production capacity is 12 million M3.

Bio-energy: Bio-energy mainly comes from agriculture and forest production and processing waste, industrial waste water and house hold waste. There are more than 13 million biogas systems for poor households in the country, producing 3300 million M3 of methane annually at present. There are more than 2200 big and middle scale biogas systems, producing 1200 million M3 of methane annually. The capacity of biogas electricity is more than 2 million KW.

Other renewable energy: Besides the hydro power, wind power, solar power and bio-energy, there are other renewable energy such as geothermal energy and ocean energy, the proportion of which is small at present.

The total capacity of new technology utilized renewable energy, without which from traditional straw combustion and big hydro power plants above 50000 KW, is 50 million tons of equivalent coal, occupying 3% of the total amount of energy consumption.

Renewable energy is clean energy that can be recycled. It is the final option of energy for the requirement of the sustainable development. The renewable energy technologies of small hydro power, wind power, solar energy and methane are matured, and the technologies of bio-gas and bio-energy electricity generation are close to matured, which have wide development prospects. It is estimated that in the next 20 to 30 years, renewable energy will play an important role in the energy structure gradually, and will make great contributes to the economical and social development. The predictions of renewable energy of our country in 2010, 2020 to 2050 are listed below.

Table 1. Predictions of renewable energy in China (to 2050)

Year	2003	2010	2020	2030	2050
Total amount of energy (100 million tons of equivalent coal)	16.8	20	30	40	60
Small hydro power (10000 KW)	3000	5000	7500	10000	20000
Annual electricity generation (100 million KWh)	960	1600	2400	3200	6400
Equivalence (100 million tons of equivalent coal)	0.34	0.56	0.84	1.12	2.24
Wind power (10000 KW)	60.5	400	2000	5000	10000
Annual electricity generation (100 million KWh)	12.7	84	420	1050	2100
Equivalence (100 million tons of equivalent coal)	0.0044	0.03	0.15	0.37	0.74
Bio-energy (10000 KW)	200	1000	2000	5000	10000
Annual electricity generation (100 million KWh)	100	500	1000	2500	5000
Equivalence (100 million tons of equivalent coal)	0.035	0.18	0.35	0.88	1.75
Methane (100 million stere)	45	100	250	300	1000
Equivalence (100 million tons of equivalent coal)	0.036	0.08	0.20	0.24	0.80
PV thermal (10000 stere)	5200	10000	27000	50000	100000
Equivalence (100 million tons of equivalent coal)	0.062	0.12	0.32	0.6	1.2
PV electricity (10000 KW)	5.5	50	3000	4000	10000
Annual electricity generation (100 million KWh)	0.55	7.5	390	540	1400
Equivalence (100 million tons of equivalent coal)	0.0002	0.0027	0.14	0.19	0.49
Others (100 million tons of equivalent coal)	0.027	0.087	1.00	2.60	4.78
Total (100 million tons of equivalent coal)	0.504	1.0	3	6	12
Proportion of Renewable energy（%）	3	5	10	15	20

***: Convert as 1KWh = 350g equivalent coal**

Table 2. Comparison of annual utility hours of different electricity generating methods (Li Junfeng, Gu Shuhua)

Electricity generating methods	Annual utility hours (hour)
Thermal electricity	5000
Nuclear electricity	6000
Gas electricity	4000
Big hydro electricity	3500
Small hydro electricity	3000
Bio-energy electricity	5000
Wind power electricity	2100
PV electricity	Connected 1300， unconnected 1100

1.2 Present situation of electric power in China and the Future Electricity Gap Analysis

The electric power supply of China before 2000 was not tight. After 2000, because of the tremendous development of economy, the demand of electric power is increasing dramatically at the annual rate of more than 20%. The phenomenon of severe electric power shortage emerged in 2003, and the shortage will not be mitigated in the next 2 or 3 years. The total installed capacity of electric power in 2002 is 356.57 million KW, of which 74.5% is thermal, generating electricity 1654.2 billion KWh, of which 81.7% is thermal. The following table shows the installed capacity of electric power and electricity generation status of our country in 2002.

Table 3. Installed capacity of electric power and status of electricity generation of China in 2002（China Electric Power Research Institute）

Generation methods	Installed capacity (10000 KW)		Generated electrical energy (100 million KWh)	
	Capacity	Percentage	Electricity quantity	Percentage
	(10000 KW)	（%）	(100 million KWh)	（%）
Thermal	26554	74.5	13522	81.7
Hydro	8607	24.1	2746	16.6
Nuclear	446	1.25	265	1.6
Total	35657	100	16542	100

According to the economic development trends and the status of resources in China at present, traditional power of thermal, hydro and nuclear can not sustain the necessary electricity supply in 2010 and 2020. There are big gaps between the supply and demand of electricity, which need to be filled up by electricity generated by renewable energy.

Table 4. Prediction of installed capacity of generator in China in 2010 and 2020(GW)（China Electric Power Research Institute）

Year	Coal	Water	Nuclear	Gap	Total
2010	400	135	12.5	37	584.5
	68.40%	23.10%	2.10%	6.40%	100%
2020	592	220	36	102	950
	62.30%	23.20%	3.80%	10.70%	100%

Table 5. Prediction of total electric power demand in 2010、2020 and 2050（China Electric Power Research Institute）

Year	Installed capacity (100 million KW)	Electricity generated (100 million KWh)
2002	3.57	16542
2010	5.85	27100
2020	9.50	44000
2050	20.0	92700

Table 6. Prediction of electric installed capacity structure in China in 2050（China Electric Power Research Institute）

<table>
<tr><th>Category</th><th>Installed capacity (100 million KW)</th><th colspan="2">Percentage (%)</th></tr>
<tr><td>Thermal electricity</td><td>10.0</td><td colspan="2">50%</td></tr>
<tr><td>Nuclear electricity</td><td>2.4</td><td colspan="2">12%</td></tr>
<tr><td>Gas electricity</td><td>1.0</td><td colspan="2">5%</td></tr>
<tr><td>Big hydro electricity</td><td>1.6</td><td colspan="2">8%</td></tr>
<tr><td>Small hydro electricity</td><td>2.0</td><td>10%</td><td rowspan="4">Renewable energy 25％</td></tr>
<tr><td>Bio-energy electricity</td><td>1.0</td><td>5%</td></tr>
<tr><td>Wind power electricity</td><td>1.0</td><td>5%</td></tr>
<tr><td>PV electricity</td><td>1.0</td><td>5%</td></tr>
<tr><td>Total</td><td>20.0</td><td colspan="2">100%</td></tr>
</table>

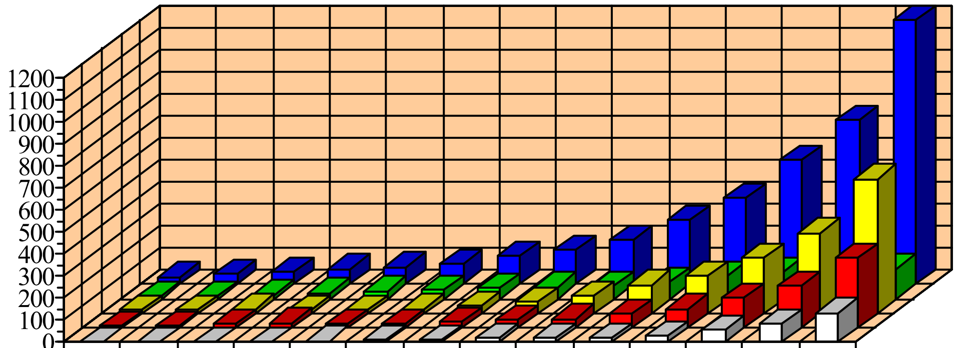
2. Present situation and prediction of PV industry in the world

Solar energy battery, which is also called photovoltaic battery, is a semiconductor which uses the photovoltaic effect to convert the solar energy to electricity. In 1954, the first silicon solar energy battery (η＝6％) and the first nuclear power plant was appeared in the USA, in 1959 the solar battery was used in space, and after the energy crisis in 1973, the solar battery became to be used in the ground step by step.

The PV generation system is divided into independent PV system and connected PV system. The independent PV systems includes the village power supply systems in the remote area, household solar power supply systems, electrical sources of communication signals, cathode protectors, solar street lights and other independently running PV systems with storage battery.

Connected PV system is connected to the electrical network, which feeds electric power to the network at the same time. At present, the technically realizable connection methods of the PV systems are Roof Connected PV Systems and Desert Power Plant Systems. In the Roof Connected PV System, the connected PV generation system is installed in the effectual area on the roof. The size of the systems varies from several KWp to several MWp. In the Desert Power Plants, big scale connected PV generation systems are built in desolate desert, whose size varies from 10MWp to several GWp.

In recent years, the output of solar battery in the world is increasing quickly. The growth rate is about 30% in 8 years and even more than 60% in 2004, when the annual output was 1200MW. Figure 4 illustrated the yearly solar battery shipment in the world.



	1988	1990	1992	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Other countries	3	4.7	4.6	5.6	6.35	9.75	9.4	18.7	20.5	23.4	32.6	55	83.8	135
Europe	6.7	10.2	16.4	21.7	20.1	18.8	30.4	33.5	40	60.7	86.4	135	193	320
Japan	12.8	16.8	18.8	16.5	16.4	21.2	35	49	80	129	171	251	364	610
America	11.1	14.8	18.1	25.6	34.8	38.9	51	53.7	60.8	75	100	120	103	135
Total	33.6	46.5	57.9	69.4	77.6	88.6	126	155	201	288	391	561	744	1200

Figure 4. Yearly shipment of solar battery in the world（PVNET2004）

3. Present situation of the PV generation market and industry

3.1 Development of the solar battery market in China

The solar battery was researched in 1958 in China, and was firstly used successfully in DFH-2 Secondary Planet. From 1973, the solar battery began to be used in the ground. Before the nineteenth century, the PV industry of our country was still at the rudimentary stage, when the yearly output was below 10KW and the price of PV battery was too high. Because of constrains of the price and output, the development of the market is slow. Besides being used as the electrical sources of secondary planets, on the ground, the solar batteries were only used in small power battery systems, such as lanterns, railway signal systems, equipment power source of alpine weather stations, electric fences, black light lamps, DC daylight lamps and so on, whose powers varies from several W to 100 W. During the period of “Sixth Five”(1981-1985) to “Seventh Five”(1986-1990), the national government began to support the development of PV industry and the PV market. National and local government funds were invested in the PV industry, which led to the consolidation of the solar battery industry and several demonstration projects in many applied areas, such as microwave relay stations, army communication systems, cathode protection systems of waterlocks and oil pipelines, carrier wave telephone systems in the country, small scale household systems, villages power supply systems and so on. During the period of “Seventh Five”, several solar battery production lines were imported, all of which were monocrystalline silicon battery production lines except one 1MW noncrystalline silicon production line. Therefore, the production ability of the solar battery in our country increased to 4.5MWp per year and the price was decreased from 80 yuan/Wp to 40 yuan/Wp.

After the 1990s, with the initial formation of PV industry and reduction of costs, its application field has been developed into industry field and rural electrization field, and its market scale expands steadily which has been listed in the national and local government plan, such as “Sunshine Plan” in Xizhang, “Bright project”, “PV Project in Ali, Xizhang”, fiber communication power supply, oil pipeline cathode protection, extending radio and TV coverage to every village, large-scale promotion of rural household PV power supply systems. In the 21 century, particularly “Sending Electricity to Villages” project in the last three years, the nation invested 2 billion with the installed capacity of 20MW which resolved the power supply problem of 800 villages without power and promoted the PV market in China to develop rapidly and greatly. At the same time, Grid-connected PV generation demonstration project began to develop quickly from 5kW/10kW to more than 100kW. Shenzhen 1MW Grid-Connected PV Station Project has became a bright spot of the PV utilization field in China.

The total installed capacity of PV systems in China has reached 65MW by the end of 2004.

A great number of solar court lamps is exported in Shenzhen, Shantou, Guangzhou and Zhejiang etc and the annual revenues have reached 500 million Yuan. The cell used by the solar court lamps is usually imported and then encapsulated by glue of which the technology is simple. The cell used reaches 6MW every year which is a large portion in the cell utilization (This portion is not counted in the statistics).

3.2 Current status of cell industry in China

During the late 1970s and the middle 1980s, some semiconductor device factories in China began to produce monocrystalline silicon cell using semiconductor industry waste monocrystalline and semiconductor device technology, and that PV industry in China went into emergence period. In the middle 1980s and late 1980s, some Chinese enterprises imported whole set of monocrystalline silicon cell and module production equipment, and noncrystalline silicon production line，the production capacity of cell/module reached 4.5MW, and that PV industry in China had been initially formed. In the middle 1990s, PV industry in China developed steadily and the production increased steadily by year. In the late 1990s, PV industry in China developed rapidly and the equipments updated continually. During 2003 and 2004, under the impulse of the “Sending Electricity to Villages” project and the international market, a set of cell production line, module encapsulation line and crystalline silicon ingot／wafer production line was put into production and enlarged one after another, so the PV industry ability in China improved greatly and the PV industry came into a complete and fast development period. By the end of 2004, the total annual production capacity in China was module 150MW, cell 67MW and silicon ingot/wafer 54MW. The outputs is about module 100MW, cell 42MW (noncrystalline silicon 4MW) and silicon ingot/wafer 46MW.

Over the past three years, due to the impulse of the “Sending Electricity to Villages” project and the international market, the cell/module production developed rapidly, the output in 2004 is six times of the output in 2002.The cell and module quality has been improved greatly and the commercialization cell efficiency has increased from 10-20% in the 1980s to 12%-14%. The costs of cell/module have decreased in the past twenty years, the price has decreased from 65-70Yuan/Wp in the 1980s to 24-28Yuan/Wp in 2003, but it returned to 28-32Yuan/Wp in 2004 due to the international shortage of solar silicon. The cell output in 2004 reached 50MWp in which 10MWp module was consumed in national PV market and the rest was exported abroad.

Through PV industry in China is developing rapidly, its industry scale and technology level has also improved. But compared to the developed countries, the gap is still very large, for example, low nationalization level of specific raw materials and few species, low quality of the nationalization materials and components such as silver, aluminum slurry and EVA. Module encapsulation low iron velour glass and TPT have not been marketed.

The PV industry chain in which the forward is small and the backward is large is imbalanced. In the chain the most serious problem is that the solar polycrystalline silicon production is blank domestically and it completely relies on import. The deficiency of other steps relies on import, such as cell, silicon ingot/module and matched materials. It can be seen in figure 5-1:

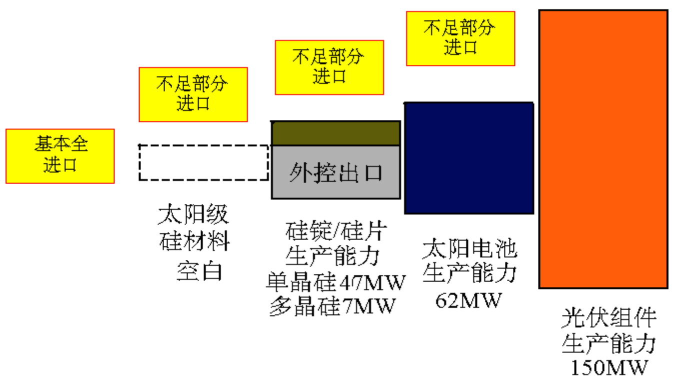


Figure 5: The imbalance of PV industry chain (crystalline silicon) development by the end of 2004

The design level and manufacture ability of the industry facilities are laggard. The polycrystalline silicon foundry furnace, fretsaw and ingot breaking machine completely rely on import；PECVD silicon nitride deposition equipment, screen printer, cell selector, series soldering machine can not meet the requirements of modernized production. These equipments should be imported in whole set and so on.

These gaps are related to the weakness of research foundation and industry foundation. Companies can establish modernized PV industry at short notice through introduction and digestion, but the matched specific materials and equipments can not catch up in short order, particularly, solar polycrystalline silicon materials. The state should organize the research of PV industry combined with chemical industry and mechanical and electric equipment manufacture, and actively seek for international cooperation simultaneously, taking solar silicon as the starting point and escaping from the technology block of the semiconductor silicon.

4. Market prediction and planning proposal of PV generation in China

4.1Development Objective by year

Development objective for each year during the “Eleventh Five-year” and 2020 are shown in the following table:

Table 7: Planned Accumulated Installed Capacity during 2004 and 2010（MWp）

Year	2003	2004	2005	2006	2007	2008	2009	2010
Incremental installed capacity		10	27	38	52	75	105	138
Accumulated installed capacity	55	65	92	130	182	257	362	500

Annual average increasing rate: 41％

Table 8: Planned Accumulated Installed Capacity during 2010 and 2020（GWp）

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Incremental installed capacity		0.20	0.32	0.48	0.75	1.17	1.82	2.84	4.42	6.87	10.65
Accumulated installed capacity	0.5	0.68	1.00	1.48	2.23	3.40	5.22	8.06	12.48	19.35	30.00

Annual average increasing rate: 56％

Table 9: PV Market in China in 2003

Market classification	Accumulated installed capacity（MWP）	Market share（％）
Rural electrization	28	51
Telecommunication & Industry	20	36
PV product	5	9
City Building PV (BIPV)	2	4
Open land（hungriness）power station		
Total	55	100

Table 10: Planned PV Market in China in 2010

Market Classification	Accumulated installed capacity（MW)	Market share（%）
Rural electrization	300	60
Telecommunication & Industry	70	14
Solar street lamp	5	2
PV product	25	4
City BIPV	70	14
Desert/Gobi power station	30	6
Total	500	100

Table 11: Prediction of PV Market in China in 2020

Market classification	Accumulated installed capacity (MWp)	Market share（%）
Rural electrization	3000	10.0
Telecommunication & Industry	4500	15.0
Solar street lamp	1000	3.3
PV product	1500	5.0
City BIPV	8000	26.7
Desert/Gobi power station	12000	40.0
Total	30000	100

4.2 Distribution of construction emphases in"Eleventh Five-years"

In the Eleventh Five-year, we should put emphases on the implementation Independent Village PV Generation Plan，fulfillment of open land（hungriness）Very Large-scale Grid-connected Station precursory project and "Central City Grid-connected BIPV" plan. We should actively provide policy support to PV commercialization development.

4.2.1. Independent Village PV Generation Plan

There are 28,000 villages, 7 million households, 30 million people without power supply. Most of these people distribute in the west of China and a few islands, some of which use diesel oil generator to generate power for 2-3 hours one day, even some are without diesel oil generator, only use ghee lamp, coal oil lamp and candles for lighting. The solar resources are abundant in these areas, so PV generation in these areas has great market potential. The following table represents the distribution of villages and households without power supply in China.

Table 12: Statistics of Village and Household without Power Supply

Province / Municipality	Counties without power supply	Towns without power supply	Villages without power supply		Total villages without power supply	Total households without power supply
			Administrative village	Natural village		
Xizhang	—	486	5,254	—	5,740	289,300
Guizhou	—	-	3,000	377	3,377	1,294,000
Gansu	—	9	871	2,384	3,264	360,173
Neimenggu	—	-	960	2,100	3,060	249,590

Fujian	—	—	960	1,400	2,360	249,590
Qinghai	1	94	773	1,254	2,121	101,000
Sichuan	—	126	1,459	40	1,625	648,300
Xijiang	—	28	216	1,095	1,339	316,200
Ningxia	—	—	—	1,306	1,306	64,000
Hubei	—	—	75	975	1,050	121,500
Henan	—	—	700	—	700	577,000
Guangxi	—	—	666	34	700	388,600
Yunnan	—	4	528	—	532	1,003,800
Hunan	—	—	—	518	518	279,500
Hebei	—	—	357	43	400	13,800
Shaanxi	—	11	344	—	355	289,100
Shanxi	—	—	259	—	259	112,000
Hainan	—	—	253	—	253	160,300
Chongqing	—	3	163	—	166	191,900
Anhui	—	—	17	33	50	80,500
Jiangxi	—	—	17	33	50	287,000
Heilongjiang	—	—	13	—	13	9,100
Liaoning	—	—	4	—	4	4,800
Guangdong	—	—	—	—	—	50,800
Total	--	761	16,889	11,592	29,242	7,141,853

The power supply problem for villages without power has been basically resolved through the "Sending Electricity to Villages" project. There are still power supply problem for villages and households without power. If we plan for each village 10Mkp, each household 400Wp and considering the enlargement of power station, the market potential will be about 3,000 MWp.

In light of current national power and policies, we try to resolve the power supply problem for all the villages with more than 50 households and 15% of the scattered households without power before 2020, to resolve the power supply problem for 1000 villages and 1 million households without power during 2006 and 2010, and the incremental PV consumption capacity will reach 265MWp, the accumulated cell used for rural electrization will reach 300MWp. The plan for each year is shown as follows:

Table 13: Planned Installed Capacity of Independent Village PV Generation during 2006 and 2010（MWp）

Year	2003	2004	2005	2006	2007	2008	2009	2010
Installed capacity		2	5	15	30	50	70	100
Total installed capacity	The incremental installation capacity from 2006 to 2010is amount to 265MWp.							
Installation costs（Yuan/KWp）				70,000	65,000	61,000	56,000	52,000
Incremental investment（Million Yuan）				1,050	1,950	3,050	3,920	5,200
Total incremental investment	The incremental investment from 2006 to 2010 is amount to 15.17 billion.							
Accumulated installed capacity	28	30	35	50	80	130	200	300
Power generation（GWh）	30.8	33	38.5	55	88	143	220	330

* The generator works for1100 hours per year.

4.2.2. Construction of Very Large-scale Grid-Connected PV Power Station

In light of current national power and policies, we should develop trial of very large-scale PV power station before 2010, and the location of the trial should meet the following requirements: the location should close to main grid(no more than 50 kilometers would be better) to reduce the incremental investment on transmission wire; the main grid should have enough load capacity to transmit the electricity from the PV power station without reconstruction; the location should be no more than 100 kilometers from the electrical load center to reduce the transmission losses; if there is no electrical load center around, there had better have a hydropower station around to convert the electricity from PV power station through pumped storage. In order to test its technological and economical feasibility it is planed that we build two or three open lands (hungriness) precursory demonstration power station of 10－20MWp before 2010 and the installed capacity will reach 30MWp.

The Chinese Large-scale (in Hungriness) PV Development Plan will be formally start up during 2010 and 2020 which is aimed to increase the installed capacity by 11,970MWp and the total will reach 12GWp by the end of 2020.

Table 14: Planned Installed Capacity in open land during 2006 and 2010（MWp）

YEAR	2003	2004	2005	2006	2007	2008	2009	2010
Installed capacity			2	4	4	5	5	10
Total installed capacity	The incremental installation capacity from 2006 to 2010is amount to 28MWp.							
Installed costs（Yuan/KWp）				50,000	47,000	43,000	40,000	37,000
Incremental investment（Million Yuan）				200	188	215	200	370
Total incremental investment	The incremental investment from 2006 to 2010 is amount to 1.173 billion.							
Accumulated installed capacity			2	6	10	15	20	30
Power generation（GWh）			2.6	7.8	13.0	19.5	26.0	39.0

*The generator works for1300 hours per year.

5. Conclusions

1. Due to abundant solar energy resources, enough building roofs and desert/hungriness resources, China has the conditions for large-scale development of PV generation;

2. PV will play an important role in Chinese power supply in the future, and it is estimated that PV will annually increase at the rate of more than 40%;

3. PV industry and PV market are developing very rapidly at present, but they have the problem of imbalance. The development of PV industry in China will be restricted if not solving the production problem of high purity polycrystalline silicon raw materials and silicon slice;

4. The linchpin of PV industry development in China lies on policies. If the

"Renewable Energy Law" will be implemented in China, and imitating the successful experiences of Germany, the financial barriers of PV industry development in China will be eliminated.

The Present Condition and foreground Prediction of Solar Energy-Thermal Utilizations in China

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Oct, 2005

Solar energy-thermal utilization is to convert directly the radiation of sun into the thermal energy to use. At present, some research and utilizations have been done in China, mainly including the solar water-heaters, the sun space, the solar cooking stove, the solar drying, the sea-water desalting and other industrial and agricultural utilization. By 2004, the present situation of above-mentioned research and utilization is shown as follows:

Item / Present situation	Solar energy water-heater (10000 m^2)	Sun space (10000 m^2)	Solar cooking stove (10000 sets)	Solar drying	The sea water desalting	Other industrial and agricultural utilization
Annual output	1350			Demonstration device	Demonstration device	Demonstration device
Total possessed quantity	6200	2000	50			

From the table, we can see that the solar energy water- heater industry has already had some production scale and great market space. This text will introduce this as an emphasis.

1. The present situation of solar energy water-heater industry in China.

1.1 A thief introduction to its development process

The solar energy-thermal utilization in China began from the 1970's of the last century. In the 1980's the energy strain caused the nation and the society to value the problem, and many civil research institutes, universities and colleges started to study the solar energy-thermal utilizations. Some enterprises gradually appeared that mainly produced the solar water-heaters with flat collectors, and integral collector storage solar water-heaters, but they developed relatively slowly. The projects of from the 7th to 10th five year plan, aimed at finding solutions to technology bottlenecks in industry, a lot of research fruit had been converted into productivity, such as: Copper-Aluminum Combined solar collector s with flat panels, all-glass evacuated tube collectors and water-heaters, the heat pipe-evacuated tube solar water-heaters etc. Especially vertical single target magnetron sputtering aluminum-nitrogen/ aluminum all-glass evacuated solar collection tube technology had been converted into productivity successfully, which stimulated the industrialization process of Chinese solar thermal utilizations in all sides. Before 1996, the solar water heater flat panel heaters dominated market, occupying more than 70%. After 1996, evacuated tube solar water-heaters gradually become the dominant product and it has occupied more than 87.5% of the market up to now.

1.2 The situation of the industry development

Industry:

The industrialization of solar water- heater is the most rapid and its utilization is the most extensive in China among all the solar energy utilization. All-glass evacuated tube solar collector was developed and produced by China independently. It keeps ahead of other countries in the terms of science and technology level, manufacturing technology and production scale and at the same time its production cost is also cheaper, so it has stronger international competitive power.

There are 300 solar water- heater enterprises in China, their annual production value is more than 12 billion RMB, Now its industrial system has been basically formed that includes raw material processing、the product development and manufacturing, engineering design and marketing serve. The industrial system has been stimulating the development of related industries such as glass, metals, thermal insulation materials and evacuated processing equipments etc. The solar water-heater industry becomes a newly arising industry whose scale is quickly extending.

Yield:

Chinese solar water-heater industry has been developing rapidly since the late 1990s, and output is increased to 13,500,000 square meters of 2004 from 3,500,000 square meters of 1998, the total possessed quantity of water-heaters are increased to 62 million square meters of 2004 from 15 million square meters of 1998, and the average possessed quantity per household is up to 7.8％, and the sale amounts to more than 20 billion RMB. We can see the industry has had a certain scale.

Table 1-1 The total output and total possessed quantity of solar water-heaters from 1998 to 2004

Year	Annual output (10000)	Increase over the previous year (%)	Possessed quantity (10000 m^2)	Increase over the previous year (%)
1998	350		1500	
1999	500	43	2000	33
2000	640	28	2600	30

2001	820	28	3200	23
2002	1000	22	4000	25
2003	1200	20	5000	25
2004	1350	12.5	6200	24

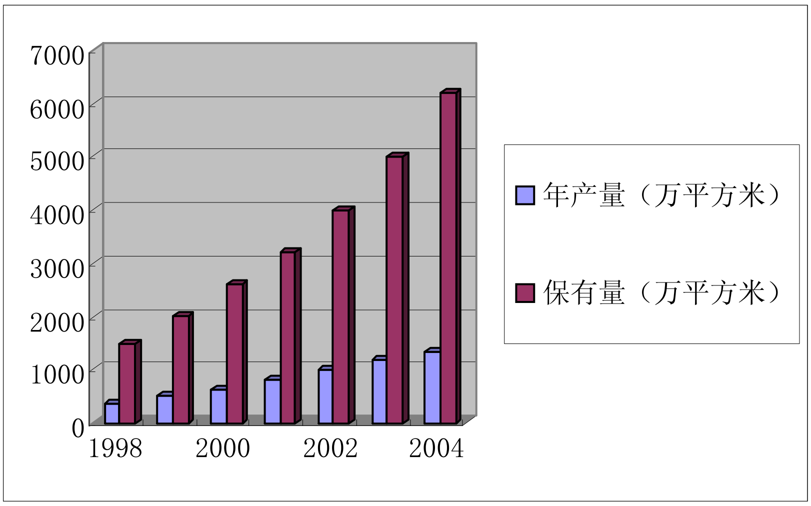

Figure 1-1 Solar water-heaters' change of total output and possessed quantity from 1998 to 2004

Product:

Now there are mainly three kinds of solar water-heaters, which is evacuated tube solar water-heaters, flat panel solar water-heaters and integral collector storage solar water heater. In 2004, the total output reached 13,500,000 square meters. Among them, the output of evacuated tube solar water-heaters are 11,800,000 square meters, amounting to 87.5% of the total output; output of flat panel water-heaters are 1,525,000 square meters, 11.3% of total output; output of integral collector storage solar water-heaters are 162,000 square meters, making up 1.2%.

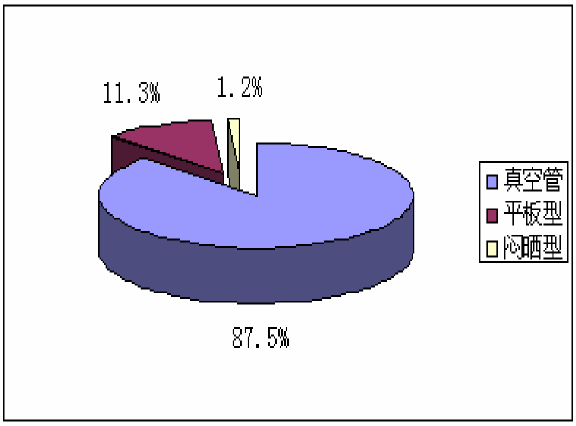

Figure 1-2 The output structures of the solar water-heaters in 2003

The all-glass evacuated tube solar water-heaters were developed by China independently and at present they are dominant products in China. In 2001 their total output amounted to 6,380,000 square meters, 61.1% more than that in 2000. In 2002 the total output was 8,550,000 square meters, 34% more than that in 2001. In 2003 the total output amounted to 10,500,000 square meters, 22.8% more than that in 2002, and among them the thermal pipe evacuated tube water-heaters had a production of about 100,000 square meters.

Market:

The market development of the solar water-heaters has entered a stage with fast growth and positive development. In 2001 the total sale was 7,800,000 square meters, which increased 27.8% over 2000; the sale of 2002 and 2003 were 9,600,000 and 11,400,000 square meters respectively, and the rates of increment were 23.1% and 18.8% respectively. Currently Chinese solar water-heaters have already entered the international market, and exported to more than 30 countries, the exporting sum up to 1 ten million US$ in 2004.

Table 1-2 Total sale of solar water-heaters from 1998 to 2003

Year	Sale (10000 m^2)	Increase over the previous year **(%)**
1998	340	
1999	480	41
2000	610	27
2001	780	27.8
2002	960	23.1
2003	1140	18.8

1.3 The engineering utilization of the solar water-heaters

- **Household solar water-heaters have become the main way that a family use the hot water**

With solar energy being thermal source, the operational cost and expense much are less than other products, and the various categories of solar water-heaters satisfy different demand of customers, so their market share increases steadily. In 2001 household possession rate of three kinds of water-heaters in China are that gas-fueled water-heaters are 20.5%, electric water-heaters 11.2%, solar water-heaters 5.7% (reckoned with the possession quantity of 2001). We can forecast that the possession rate of three kinds of water-heaters will arrive at 22.9%, 15.4% and 12.3% respectively in 2004 and the market share of solar water-heater will reach one third, which is prominent.

- **The engineering utilization that the solar energy water-heaters combine with building construction is an important way of buildings energy-saving.**

In 2002 about 27.5% of the total energy consumption came from buildings in China and the number is about 450 million tce when converted into tons of coal equivalent. In 2020, the percentage will be about 23% to 25%, and the energy consumption of buildings will be 760 to 790 million tce. We can forecast that in 2010, the heat-collecting area of the solar water-heaters will reach 150 million square meters which can substitute other energy about 50 million tce annually. If the total quantity of the solar water-heaters can reach 300 million square meters, then they can substitute about 2.50 million tce energy which makes up about 6.5% of total energy consumption of buildings, and equals to 6 times of present figure and 1.6% of total energy consumption in 2020. Thus it is clear that the solar energy will contribute to energy saving of buildings and the demand of total energy.

Under the support of the national policy, many places in China have set up a lot of solar energy demonstration region. As demonstration work that combine solar energy and buildings gets good effect, commercial demand is also in the gradual growth. More and more people living in such buildings as schools, guest hotels, bathing centers and residences use solar water-heaters to provide living hot water. The producers and dealers are all actively popularizing such utilization in the engineering construction (collective installing or hot water engineering). The engineering utilization of the solar energy water-heaters is just at the beginning and will have a rapid development in the future.

- **The utilization of air-conditioning and heat supply**

The technology of heat supply and air-condition with solar energy has already started to get into practical stage. In Jan. 1998, Guangzhou energy institute of Energy Conversion of Chinese Academy of Sciences successfully developed solar air-conditioning water heating system, and was used in the Jiangmen municipal of Guangzhou province. The temperature of hot water used for refrigeration is from 75℃ to 65 ℃ and the temperature of living hot water is from 55℃ to 60℃. It is equipped with highly efficient flat panel collectors whose area is 500 square meters and a two-stage absorption refrigerator, and it can satisfy the air-conditioning load of 500 square meters. The Solar Energy Institute of Beijing has set up 100 kW solar air-conditioning system in Rushan municipal of Shandong province that uses thermal pipe evacuated tube collectors and one-stage absorption refrigerator operating under medium temperature. In 2003 the institute itself set up two comprehensive demonstration projects, and one is 100 kW photovoltaic electricity-generating system , and another is 300 kW solar energy system for air-conditioning and heat supply and the institute uses solar energy to supply electricity、air-conditioning、heat and living hot water. The demonstration project will provide experience and data for both the combination of solar energy and buildings and the comprehensive utilization of solar energy photovoltaic electricity and photo-thermal. The project shows the benefits of solar energy utilization. The Beijing Olympics scientific and technological projects “the demonstration of new energy comprehensive utilization in buildings” developed by Beijing Tianpu solar energy industrial company Ltd. used evacuated tube air-collectors to ventilate in the summer and produce heat air. The project provides abundant experience for the combination of solar energy and buildings.

2. The foreground forecast of the solar energy development

The solar water- heater is a kind of green energy product that has the advantage of saving energy、environmental protection、economy and convenience. Utilizing solar water-heaters is a practical, economic and effective means to provide low-temperature hot water for household living and provide low-temperature heat for industrial and agricultural production, thus it has wide development space and huge market potential. The combination of solar energy air-conditioning and heat supply, water-heater technologies with buildings is a sustainable, effective and environment-sound way to reduce the energy consumption of buildings. Especially for China where energy and resources are relatively scarce, the way is quite significant.

2. 1 Emphasis of research & development about technologies and industrial fields

2.1.1 The research of low-temperature hot water technology

- **Flat panel collector**

a. Adopt the superior collector core and gradually develop high-quality all-copper collector core;
b. Adopt the high-quality selective coat;
c. adopt high transparency material as cover material;
d. Adopt transparent heat-insulation materials to repress the convection and reduce the loss of heat;
e. develop module collector on roof of building

- **all-glass evacuated tube collector**

a. Develop the glass evacuated collector with metal runner inside;
b. Heat pipe evacuated tube;

- **integral collector storage solar water heater**

a. develop and research different levels of integral collector storage solar water heaters;
b. develop integral collector storage solar water heater with evacuated tube.

- **Solar energy hot water system**

a. Develop all kinds of all-weather solar hot water system that can be use through the whole year, for example, develop two times circulatory system with heat exchanger and assistant heat source ,whose quality is equivalent to international products;

b. Develop applied software and hardware (components and parts) of the solar hot water system.

In 2020 Chinese solar energy low-temperature hot water technology will reach international advanced level in such ways as its levels, science and technology, industrialization and scale. China will become an international base of processing, importing and exporting solar energy low-temperature equipments;

When solar energy heat supply and become practical, science and technology result will be converted toward productivity and coupled with generalizing in many places, the technology will be industrialized basically.

2.1.2 The development and research of medium-high temperature technology

- Develop medium-high temperature technology of solar energy heat utilization, and generalize the solar energy heat utilization technologies in desalting sea water and other fields of industrial and agricultural application.

- Research and develop solar energy thermoelectric technology, introduce the related equipments and technology, realize regionalization, set up trillion watt class solar energy thermoelectric station before 2010.

In 2015 the technology of solar energy medium-high temperature utilization should reach or be close to the international level.

2.1.3 Industrial development direction and emphasis fields

Developing direction:

- Entering the building industry is an important path to accelerate the industry development and standardize the markets of solar thermal utilization;

- Extend the fields of utilizing solar energy hot water, get into other proper fields by demonstration;

- Increase the demand of residents in the country and small-medium towns for low-temperature hot water, which should be main market direction of solar water-heaters.

Emphasis fields:

- Solar energy collector and its water heating engineering systems
- Integral technology of combining solar energy with buildings
- Solar energy heat supplying, air-conditioning and heat keeping technologies
- Active sun-space technology
- The technology of desalting sea water with solar energy
- The technology of solar energy drying and other application in industry and agriculture
- The technology of solar energy medium-high temperature utilization (solar energy thermoelectric technology)

2.2 The predict of market development

The solar energy heat utilization has huge market potential.

- **Solar water-heaters are favorite by the most customers in virtue of its advantage such as energy saving and environmental protection**

After more than 20 years of reform and opening, Chinese social productivity, comprehensive national strength and people living levels have all ascended a big step. With the national economy and the people living level continuously rising, the need of residents for indoors hot water gets more and more strong. According to a research, in 2020 every person will need about 40 kg of living hot water every day on the average, and the total consumption in China will reach 20 billion tons. At that time possessed solar energy water-heaters in China will reach 300 million square meters, which can produce 13 billion tons of living hot water and save about 135 billion kilowatt-hours electricity, about 65% of total electric demand.

Year	Annual output (10000 m^2)	Summed quantity (10000 m^2)	Chinese population (100,000,000)	Possessed quantity per thousand people (m^2)
2004	1100～1200	6200	13	47
2010	2600～3000	15000	13.71	109
2020	4500 --5000	30000	14.3	210

- **Combination with buildings will further stimulate the market**

During the tenth five year plan, Chinese construction and real estate industry will develop with quicker speed, and the total area of finished town residence are 2,700 million squares meters; In 2005 the per capita housing construction area of town residents has increased to 22 square meters, and on the average every household has a dwelling house with basic function. As the combination of the solar water-heaters with buildings gets further perfect, solar water-heaters will provide 6.5% of total energy demand in the near future, which will tremendously stimulate the solar water-heater application in buildings.

- **The construction of small towns can expand a larger market**

There are 1,300 million people in China, 75% of which live in the rural region, so this is a huge market for solar energy utilization. Owing to the reform and opening policy, the rural economy increases very quickly, and there are a great deal of rural houses and small town residence, so the need for living hot water increases greatly. In 2000 the total construction area of village houses was 17,500,000,000 square meters, and the number will increase 8,500,000,000 square meters in 15 years henceforth, that is the total construction area of village houses will reach 26,000,000,000 square meters. In 2020, if the universal rate of the rural solar water-heaters comes to 75%, the possessed quantity in rural China will reach 170,000,000 to 180,000,000 square meters, 60% of the national total amount, which will play a important role in protecting ecosystem environment, preventing water and soil from losing and perfectly resolving the energy demand in rural regions. It is not practical technologically and economically that the dispersed villages use natural gas or electric power as everyday energy, which provides opportunity for exploiting rural market of the solar water-heaters.

2.3 Form mature national industries with international competitive power

As a newly arising industry, the technology and market of solar water-heaters has been developing continuously. National relevant departments attach further importance to the industry, reinforce macro management and instruction, and help it to become a new source of national economy growth. Guidelines of developing the industry are that it should be guided by market demand, dominated by enterprises and supported by technical progress, and government should strengthen macro instruction, foster and standardize the market, gradually cause enterprises to enlarge scales, products to standardize, technology to regionalize and market to standardize.

The national relevant departments and governments at all levels have already started to bring the solar water- heater technology development and innovation into its scientific and technological development programming, gradually increase the strength of supporting new product, new technology research, and raise the conversion rate of technological output; Encourage enterprises to integrate with universities and colleges, research units to develop the new technologies and new products; encourage enterprises to increase the input of science and technology development, help to establish a enterprise-dominated system of technological development and innovation, gradually improve enterprises' independently creative ability.

The national relevant departments is actively carrying out important technical demonstration , support enterprises in raising equipment level, improve the product quality and productivity, lower the cost of production; encourage enterprises to continuously develop new technologies, new products, increase species and specification of products, extend the range of application, form some famous brand products with higher prestige at home and aboard; Guide adjustment of the industrial structure and the product structure, encourage to develop the third industry engaged in the solar water-heaters' engineering, installing and service. By macro adjustment and market guide, promote industrial upgrading, foster many national industries with the international competitive power.

3. Assuring system of solar energy water heater industry and market development

3.1 Assuring system of technology development and progress

- **The technological development and input**

The Chinese government attaches importance to the solar water-heaters industry at its beginning. The national and regional governments established a series of research development projects concerning the renewable energy and solar energy thermal utilization, and continuously enlarge science and technology devotion and input, such as "863 projects", "973 projects", natural science fund etc. The input of the seventh five year plan was 30 million RMB; input of the following three five year plans was respectively 30 million, 60 million, 40 million RMB. During the tenth five year plan, "863 projects" was input about 180 million RMB. Among them, an important research is to develop the key technologies of solar energy water-heaters. These research have Obtained many important technological results, one of which is the evacuated tube technology. The technology was developed in the "75"period, began to industrialize in the "85"period, and at present have already occupied more than 87.5% of water-heater market.

- **Capital Support and credit and loan**

The fast development of the Chinese solar water-heaters industry is partly owing to capital support of the government. The government continuously enlarges the input of the industry in the way of technical innovation loan and national debt funds， implement the integrated plan of producing, learning and studying. From 1987 to 1997, the government annually spent 120 million RMB of technical innovation loan on renewable energy enterprises' innovation, including some key enterprises in the solar energy industry. In 2002, the government allocated 175 million RMB of technical innovation loan and national debt funds to support Huangming Company, Huihuang Company and Liguang Company to transform production line and upgrade the industrial and the companies got 30 million, 15 million, 15 million RMB respectively; Some regional governments also gave corresponding financing support, for example, Beijing Municipal allocated funds of 8 million RMB to Sangpu solar energy technical company, and Chongqing Municipal loaned 50 million RMB to Beipei General Glass Factory etc.

- **Establish the research & development center dominated by enterprises**

With the national related policy guiding, the Chinese solar water- heater industry have formed an independent research &development system dominated by enterprises and supported by universities and national institutes. For examples, Tsinghua University independently developed vertical single target magnetron sputtering aluminum-nitrogen/ aluminum selective absorption coating technology (national invention patent),and have built up a relatively sound product research & development center; Huangming Company of Shandong Province set up Huangming-Zhongke laboratory cooperating with Engineering Physics institute of Chinese Academy of Sciences, established common research & development cooperative relation with the University of Sydney in Australia; Linuo of Shandong province together with a German company set up cooperative development corporation; Beijing Sangpu company continues to perfect test system of solar energy heat utilization; Other enterprises also have been creating condition and preparing to build up their own research & development organization. The whole industry owns its own core technologies and intelligent property right.

3.2 Product quality control system

- **The solar water- heater standardization system have formed basically**

So far, our country has already promulgated 16 solar water- heater national standards, and 3 professional standards, which basically constituted the solar water- heater technical standard system of our country and provide the technical laws and regulations for the development of solar energy water-heater industry.

- **Basically form test and certificate system**

In order to promote healthy development of the solar energy water-heater industry and to speed up the construction of the industry commercialization ability, the former National Economy and Trade Commission supported the construction of the national class solar water-heater quality check center and the product certificate by supporting the project of accelerating the construction of Chinese renewable energy commercialization ability" which is studied by the United Nation Development Program (UNDP) and Global Environment Foundation (GEF). Three national quality test centers have already been set up in Peking, Wuhan, Kunming and a certificate center have been set up in Beijing and will begin to operate formally in 2004. The quality control of Chinese solar water-heaters will be standardized and get on a new stage.

3.3 National legislation

The 14th Session of Standing Committee of the tenth National People's Congress on 28 February 2005 had passed “the renewable energy law of the People's Republic of China”, which will come into force on 1 January 2006.The implementation of the law will give dependable legal assurance to the development of such renewable energy as solar energy, and will bring new opportunity and new development situations for the solar energy water- heater industry.

4. Problems and suggestions

4.1 Strengthen the development and generalization of the new technologies and products, improve technological development ability and technical equipment levels, encourage and support industrial upgrading and technological progress.

We must stick to the scientific and technological progress and innovation, continuously improve and raise the technical level of solar low-temperature heat utilization of our country, develop new technologies, new processes and new products, serve the industrial development, ensure the industry to develop sustainably, rapidly and healthily. We should continue to keep lead in industrial scale and at the same time catch international advanced level in technologies.

Develop the integrated technologies of the solar energy and buildings and make the solar energy become safe, stable, dependable energy that can be used as low-temperature thermal source of buildings. The integral technologies include engineering programming, design and process technologies, complementary technology with conventional energy, control technologies, etc. The integration of solar energy with buildings requires buildings to be energy-saving ones. Active and passive sun space is a kind of such building that have significant energy-saving effect, so national relevant departments should attach much importance to it, especially should strongly generalize it in most of rural regions.

Enlarge the application of solar low-temperature thermal utilization technology, actively develop the technologies of solar energy heat-supply and refrigeration, seawater desalination and other utilization in industrial and agricultural fields.

4.2 Cooperate with other countries, introduce, digest and absorb foreign new materials, new processes and new technologies that can make heat-collecting, heat-keeping much more effective, such as high efficient coating technology, heat-isolation materials, and try to realize their regionalization.

Follow the technological front-line of the international solar energy thermal utilization, concentrate advantages to develop fundamental research and application study of solar high temperature utilization technologies.

Set up enterprise-dominated system of researching and developing Chinese solar thermal utilization, establish national class open laboratory, make full use of regional talents, study and experiment new materials and technologies; select and support conditional large enterprises to build up research & development centers, making our country reach international pioneering level in the way of solar thermal utilization.

4.3 Standardize the market of the solar water- heater product

Market management sectors at all levels should strengthen supervision, manage according to laws, strictly execute laws, fight counterfeit and inferior products; Eradicate completely arbitrary charge, test, fines and regional protectionism; Our country doesn't encourage to practice the certificate of producing and selling for solar water-heaters, governments at all levels should guide and request enterprises to carry out national related standards, and if a kind of product have passed standards, regional government must not test it repeatedly with other excuse; every regional government should guide enterprises to observe related laws such as Law of Product Quality, Law of the People's Republic of China Against Competition by Inappropriate Means and Law of the People's Republic of China on the Protection of Consumers' Rights and Interests Protection.

4.4 Direct and encourage enterprises to set up modern enterprise system, operational mechanism and management mechanism, raise management level and comprehensive strength

Encourage and forge resource reorganization, integration, and scale management in the solar energy industry; Support a batch of backbone enterprises that have independent intelligent property right and international competitive ability.

4.5 Make good publicity, strengthen training and information propaganda

propagandize the significance of utilizing solar energy in various media and ways, popularize the solar water-heater knowledge, recommend new technologies and new product; Properly hold product exhibition, and put advertisement; strengthen the propaganda about integral technology of solar energy and buildings.

Strengthen the publicity of relevant standards, regularly train workers who are engaged in technologically researching, managing and selling solar water-heaters, so as to enhance their ability and quality. Take various forms and channels to foster every kind of professional talents, roundly enhance competitive ability of the industry.

Strengthen the statistical system construction and informationization of the industry and enterprises, guide industry to develop healthily by information dissemination.

4.6 Special legislation of solar energy thermal utilization

Domestic and international experience proves that it is necessary to get the support of governments so as to develop new energy and renewable energy utilization. The most effective way is legislation. Now our country had passed Laws of Renewable Energy, but it is not enough and it is necessary to constitute various special laws such as Laws of Solar Energy Utilization; these special laws should definitely give various energy such as the thermal energy, fuel, oil etc. the same support policies with electricity development. Every regional government may establish regional renewable energy law according to regional resources, economy, social condition and actual condition of renewable energy industry development.

The Expectation of Biomass Power Development in China

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Biomass power is important renewable energy resource that replaced oil and gas as one of the main strategic energy resources. Biomass power, which is clear and efficient technology, has advantages of high generation efficiency and protecting environment. The research and application demonstrate that advanced biomass power generation efficiency has reached 40%, with high energy utilization efficiency. The carbon dioxide exhausted is equal to absorbing amount in biomass renewed process, thus the carbon dioxide exhausted is null. It has important contribution to alleviating and solving greenhouse effects. There is abundant biomass resource, about 15% of primary energy exploited in China, occupying the second place after coal. 30% in rural area energy is still biomass.

1. Biomass resource status

Biomass is multiform in China, including agricultural residue, firewood, forestry residue, organic waste (such as livestock excreta, municipal domestic waste), industrial waste (grain factory, paper mill, timber mill, sugar refinery, brewery, food factory). Agricultural residue is the biggest biomass energy resource in China, more than 50% of total (Figure 1). The biomass contains lots of energy, estimated at 487Mtoe each year, about 370Mt (76%) is used for power and heating, the other 117Mt is used for fodder and muck in rural areas.

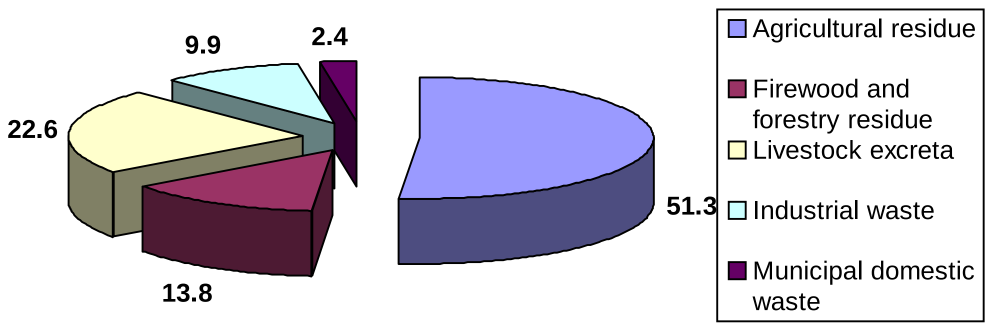

Figure 1 The structure of Biomass energy resource in China (%) (Total 487Mtoe)

1.1 Agricultural residues

China is large agricultural country, the production processes of crops such as rice, wheat, corn, beans, tubers, cotton and sugarcane produce a good deal of agricultural residues, one of the most important sources of biomass in China. It produced 715Mt agricultural residues, amounting to 250Mtoe energy. Figure 2 shows the energy potential of various agricultural residues. Rice, wheat and corn are three major crops, which produce 70% of agricultural residues.

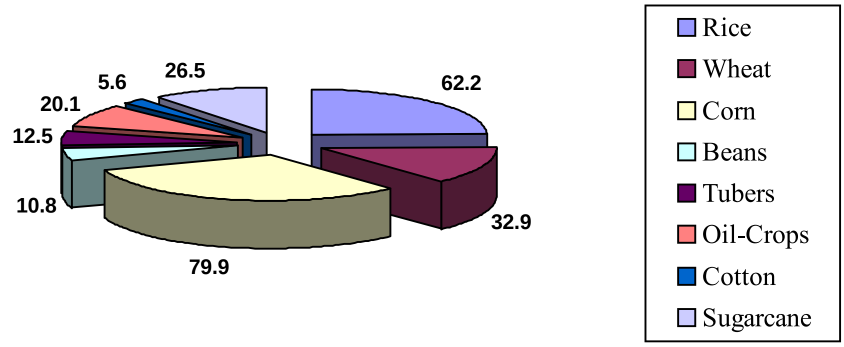

Figure 2 The output and energy potential of various agricultural residues (mtoe, 2001)

1.2 Forestry residues

Forestry residue is another important biomass resource. The forest of China is mainly distributed in the northeast, southwest, northwest and southern hill areas. According to the fifth national forest reserve survey (1994-1998) completed in 2000, the stock of timber is 12.49billion m^3, increased by 4% than the fourth. in China, the consumption of the timber is mainly composed of three parts: 44.2% used to make woodwork, 33.1% consumed by timber mill and farm, the rest used to life fuel. The firewood and forestry residues is about 157Mt, amounting to 67Mtoe in 1998.

There isn't bioenergy crops industry now in China. According to statistics, China has 1.3million km^2 cultivated land, and 1.08million km^2 isn't reclaimed yet, including 354,000km^2 available cultivated land. It will produce biomass 177Mt or 80Mtoe if the 354,000km^2 land is used to grow bioenergy crops.

1.3 Livestock excreta

In China, the livestock is composed of 447million pigs, 290million sheep, 5.28billion fowls and 151.5million large animals such as horse, cattle, donkey, mule and camel in 2000.Thus the total amount of the excreta weighed up to 320Mt or 110 mtoe .

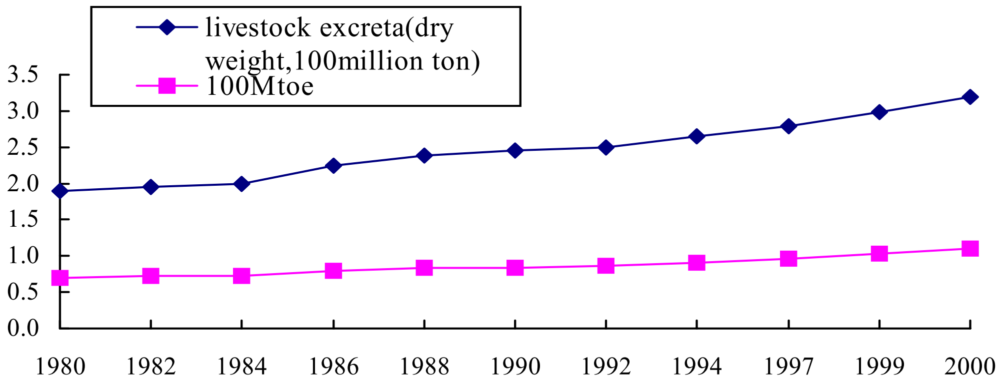

Figure 3 The increasing trends of biomass energy of livestock excreta

1.4 Municipal domestic wastes

The municipal domestic wastes are the mixture of household, commerce and service rubbishes, a few construction wastes. Many factors affect their composition and quantity, such as urban population, resident income, fuel structure, eating habit, urban construction and season. The rubbish composition between different cities differs significantly, especially organic material. The organic composition in the developed city is high and generally higher in the southern cities than the northern ones. The waste heat value is different among cities, which is 4500kJ/kg in Beijing, Guangzhou, Shanghai, Shenzhen, etc., about 3400kJ/kg in most areas. The municipal domestic waste is produced about 150Mt or 15Mtoe each year and increasing by 10% more or less.

1.5 Industrial wastes

Industrial biomass resource is the solid wastes produced by grain processing plant, paper mill, timber mill, winery, sugar refinery and food factory. It is estimated that it will produce 48Mtoe industrial solid wastes, including 18Mtoe crop chaffs, 0.3Mtoe papermaking wastes, 60 Mtoe wood processing wastes.

2. Biomass power technology

With the economy sustainable and rapid developing, people’s living standard is improving, and the demand for the electricity is increasing year by year. Thus electricity shortage in recent years has not been solved completely yet. Some remote areas are lack of electricity for a long time. Therefore it is meaningful for alleviating the pressure of energy supply and social sustainable development that utilizing biomass energy in advanced technology.

2.1 Direct combustion

The key technology and equipment of direct combustion are biomass boiler and small-scale steam turbine generating set. The small-scale steam turbine technology generally is mature, low cost but unefficient (Table 1).

Quite a lot of boiler manufacturing enterprises have already produced various biomass boilers, the technology is mature. The central kinds are firewood (sawdust) boiler, bagasse boiler, chaff boiler. Furthermore the boiler capacity, pressure parameter, etc. can be designed according to the needs of user. The series of firewood boiler and bagasse boiler is various, used extensively and broad range of capacity, pressure and temperature. But because the domestic biomass fuel supply is insufficient, it is mostly medium and small capacity products in the domestic market, the large equipment is mainly exported to the international markets where biomass supply is concentrate and sufficient. Chaff boiler is used less because of small capacity, which is applied to enterprises with sufficient chaffs, lack of large-scale and concentrating biomass power plant.

Table 1 small condensing steam turbine capability

Steam turbine size （kW）	Parameter		Total Steam flow （t/h）	Unit consumption （kg/kWh）	Generation electricity efficiency （%）
	(MPa)	(℃)			
1500	2.35	390	8.4	5.60	20.0
3000	3.43	435	14.8	4.93	22.1
6000	3.43	435	28.5	4.75	22.9
12000	3.43	435	55.6	4.63	23.5
25000	3.43	435	111.0	4.44	24.5
25000	8.83	535	91.0	3.64	28.5

2.2 Mixed combustion

The biomass density energy is low, the volume is large and the carbon dioxide emission increase during the transport course, thus it isn’t adapted to large-scale and concentrating biomass power plant. However, the scattered small-scale biomass power plant is high investment and labour cost, low efficiency and benefit. It becomes new concept that combusting the mixture of biomass and fossil fuel in large-scale coal-fired power plant. It not only offers the chance that optimizing biomass and fossil fuel mixed, but a lot of extant equipments also haven’t to change largely, making the investment cost low. Moreover, large-scale power plant is adjustable, adapting to various mixture fuels and making the device adapt to local biomass characteristics.

Most coal-fired power plants burn the fine coal; biomass must pass through the pretreatment, because the machine for rubbing coal is unsuitable for crushed biomass such as the bark, forest residue or block, etc. Biomass and coal mixed combustion is very potential. This simple technology can reduce the carbon dioxide emission obviously. Biomass mixed combustion is divided into four modes:

a) Biomass combustion is in an independent system, the heat produced is used for the boiler of the power station;

b) Biomass combust on stockers assembled in the furnace coal-fired boiler;

c) Biomass crushed by special pulverizer combust with coal in boiler;

d) Biomass after gasification convert to the boiler gas fuel.

Although biomass mixed combustion power technology is economical, it seldom applies in China. Because it is short of effective operation and intendance means, out of subsidy or protecting policy.

2.3 Biomass gasification

China developed biomass gasification technology in the early 1960s. on a base of chaff gasification technology, it made a farther research on biomass gasification technology, mainly study on generation capacity and different biomass materials, successively developing various generating sets from 2.5kW to 200kW. In recent years, China thinks much of the research and application of medium-small scaled biomass gasification generation technology. The developed technology has the characteristics of low investment and flexibility. The capacity of biomass gasification generation system developed is from less than 1MW to 6 MW. The gasifiers have four structures: layer downdraft gasifier, open gasifier, downdraft gasifier and circulating fluid bed gasifier. It adopts the single gas internal combustion engine and double internal combustion engine. Single system's power is amount to 400 kW practically. The MW-class gasification power system developed from single gas engine to gas-steam circulating cogeneration electricity, the system efficiency increased from 18% to 28%. Circulating fluid bed power generation from gasification system has economic benefits for treating with numerous biomass, thus it spreads fast in China and becomes the most medium gasification power system applied in the world.

As advanced power generation from gasification, biomass IGCC consumes lower than conventional system, efficiency is more than 40%. Since 1990, many advanced countries started the relative research. It is still in the stage of R&D.

2.4 Technical application conditions

The biomass direct combustion power technology is efficient and unit investment is reasonable in large scale. But it requests the biomass concentrated. Considering collection and transportation, its cost is high for numerous biomass. Thus it's suitable for the modern big farm or large processing plant, not suitable for scattered biomass in the developing country.

Medium-small scaled biomass gasification for power generation technology is mature in developed countries, but it is uncompetitive due to small scale and complex process. And its cost(above 1200 dollar/kW) and run cost are high, so it difficultly enters the market of developing country. However the technology developed in China has the characteristics of low investment, low cost and flexibility, one of the most competitive technology. The small-scale biomass gasification for power generation technology, which is suitable for utilizing scattered biomass, has been in the business demonstration stage. It accords with the conditions of developing country.

Table 2 Biomass power technical characteristic comparison

Generation mode	Direct combustion	Gasification combustion	Mixed combustion	Mixed Gasification combustion
Characteristic	utilize the stream from boiler direct combustion；	through gas turbine or gas engine after gasification；	mixture of biomass and coal combust directly in boiler；	biomass after gasification combust with coal in boiler；
Advantage	mature technology, larger scale, simple material pretreatment, reliable equipment, low run cost；	low pollution Small scale, high-efficiency, flexible, low investment；	simple technology, Use conveniently, lowest investment if don't improve equipment；	current, less impact on coal-fired system, obviously economical；
Disadvantage	high pollution, small size, low efficiency, unitary material, high investment；	complex equipment, immature large-scale generation system, high equipment maintenance cost	require treatment strictly, impact on original system；	add gasification equipment, complicated management； corroding the metal；
Application condition	large-scale generation system（>20MW）；	medium and small-scale generation system；	timber materials、Special boiler；	generation system disposing of vast biomass；

2.5 Economic analysis of biomass power technology

2.5.1 Economic indicator

Table 3 Economic indicators of various biomass power technology

Indicator	Biomass power technology			
Installed capacity（MW）	24MW	6 MW	6 MW	3 MW
Generation mode	import direct combustion	domestic direct combustion	efficient gasification	simple gasification
Generation efficiency(%)	25.6	19.5	25.6	18.0
Runtime（h/a）	7500	6500	6500	6000
Consumed electricity (kW)	2400	600	600	150

Electricity capacity（MWh/a）	180000	39000	39000	18000
Biomass consumption (kg/kWh）	1.05	1.37	1.05	1.48
Material price（RMB/t）	171	155	155	155
Consumables cost（RMB/kWh）	0.0265	0.0265	0.045	0.05
Electricity sold（MWh/a）	162000	35100	35100	17100
Staff	150	60	60	35
Staff expenses（RMB/person•a）	25000	25000	25000	25000
Equipment maintenance rate（%）	1.5	1.5	1.5	1.5
Own capital input（thousand RMB）	92400	13650	13650	4725
Loan（thousand RMB）	171600	25350	25350	8775
Theoretical grid price（RMB/kWh）	0.600	0.574	0.535	0.551

Notes: 1. materials price is calculated by distance: 155RMB/t less than 15km, or else 171RMB/t;
2. Own capital is calculated at 35%, others is loan of 5% interest;
3. Theoretical grid price is calculated at 10% of total investment internal rate of return.

2.5.2 The impact of different conditions on biomass power economy

Figures 4-7 show the impacts of different conditions on biomass power economy.

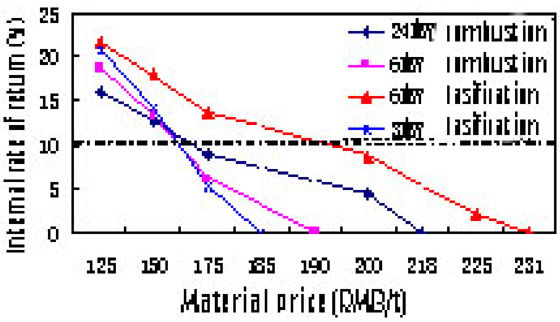

Figure 4 The relation between material price and internal rate of return

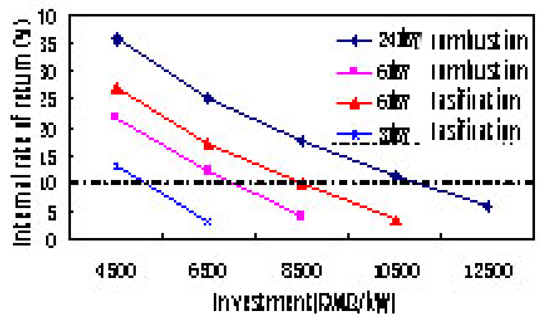

Figure 5 The impact of investment cost on internal rate of return

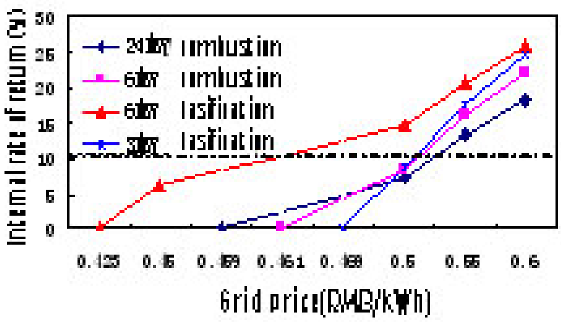

Figure 6 The impact of grid price on internal rate of return

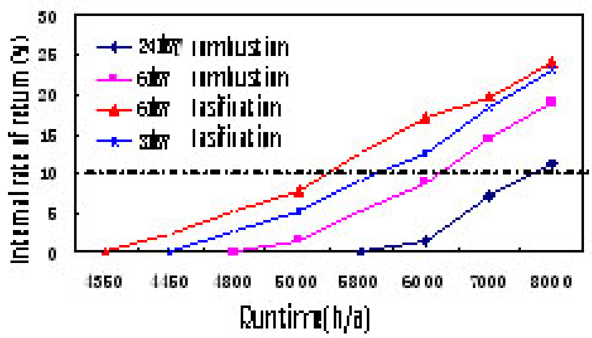

Figure 7 The relation between Utilization of capacity and internal rate of return

Power generation efficiency is very sensitive to the material price, the expensive material could be used to efficient equipment. Generally speaking, assuring the internal rate of return 10%, the material price must be controlled at about 175RMByuan/t, under the condition of 0.52RMByuan/t grid price. It is difficult to appear in most areas, specially more difficult for large generation system demanding for collecting and reserving a mass of materials.

The unit investment of equipments is an important parameter in the person of technology economic benefit and competition. The investment internal rate of return of the 24MW equipment imported is biggest, under the same investment cost (Figure 5). Under the current price(imports 11000 RMByuan/kW, domestics 6500RMByuan/kW), The investment internal rate of return of the domestic equipment is higher than that of import, thus domestic equipment is more competitive than import, though domestic equipment efficiency is less than import.

The grid price is relative to electricity generation cost directly. The low cost project can support lower grid price. Generally speaking, among the same type technologies, the more efficient it is, the lower run cost is; the bigger the scale is, the lower run cost is. Attentively, the run cost of mature technology is low, because of the different demands for equipment maintenance. Therefore the expensive fittings of imported equipment bring on high run cost. Keeping the investment internal rate of return about 10%, when the electricity is generated by imported equipment, the grid price is supposed to be 0.6RMByuan/kWh. And it is 0.535RMByuan/kWh when electricity is generated by gas-surplus heating utilized system. But the unefficient equipment is more sensitive to price (Figure 6).

Utilization of capacity is a synthetical reflection of technology used. The higher utilization of capacity is, the maturer technology is. However, the higher utilization of capacity designed demand for more dependability of technology and material supply. In order to attaining 10% internal rate of return, movement time of the 24MW equipment is requested to run 8000 hours, namely the utilization of capacity is 91.3%. This request is strict, it is difficult to utilization of capacity attaining above 90% all of the year, especially straws that is various, distant-collected, frequently replaced material.

3. The development trend of biomass power technology

Biomass power technology will be limited by its characteristics and the situation of our country, which will be divided into three modes: miniaturization and approach to the End-User, integrative utilization and co-supply of combined gas-heat, distributed power system.

3.1 Miniaturization and approach to the end-user

Limited by materials, it is the easiest technology to come true for miniaturization and approach to the End-User. Taking grind mill as example, the output of chaff limited by production isn't low. Therefore power station corresponding to the output of chaff is the most economical. And the power as supplement of grind mill, supply to the production and life directly. It saves the grid part, reduces the investment, simplifies the system, reduce the run cost. Utilizing the biomass resource in existence, the mode of approach to the End-User is the most valid directly and prone to apply.

The sugar refinery used cassava and sugarcane as materials, medium-small scale slaughterhouse, Livestock farm and timber factory are all potential users of miniaturization and approach to the end-user.

3.2 Integrative utilization and co-supply of combined gas-heat

Improving the system efficiency is a basic measure to utilize biomass resource most effectually. In large-scale biomass power system, the integrative utilization and co-supply of combined gas-heat is prone to improve the efficiency. It adopts many combined technologies and combined gas-heat production technology to optimize the system, improve the efficiency and utilizing biomass resource most effectually, according to different material characteristics, user's demands and crafts. The large scale slaughterhouse, timber factory and the areas where agricultural and forestry residues concentrated are all potential markets.

3.3 Distributed power system

Considering the power grid security, distributed power system is considered as the best means. The intending power system should be combination of concentrated and distributed systems. The central structure is composed of concentrated generation electricity, distant main-stem transmission network, regional distributed network and distributed power system principally composed of minitype network. Biomass power system is convenient and prone to realize, which applies clean, efficient and reliable power to end-users, whichever mode and whatever scale it is.

3.4 Development perspective

In 2010, it is concentrated on large scale biomass gasification power technology, spreading direct combustion technology and developing IGCC generation electricity system for business at the same time in developed countries. In the USA, the 6MW and 60MW IGCC projects as industrial demonstration application will be completed in 2010 or so. The total installed capacity will reach 6.1GW in 2010 and generate electricity 200TWh in 2020. In 2030, the living biomass power technology will marketize completely, as one of the central energy in 2030.

China is in the stage of biomass power technology developing and applying to business, during 2000 and 2020. Biomass gasification for generation electricity should apply to business in the areas where biomass is abundant and energy is absent and expensive. Biomass direct combustion technology should apply where biomass is concentrated and industry demands for more energy.

4. Barriers to biomass power technology and recommendations

There are three barriers restricting the application of biomass power technology in China, they're technological barriers, economic barriers, and policy barriers. The barriers are different with other countries due to the situation of China.

4.1 Technological barriers

The research on biomass power technology is scanty, because of scanty capital for research and powerless equipment enterprises in China. It is mainly attended to research on medium-small scale biomass gasification technology for generation electricity, and boiler or other pyrogenation equipment enterprises develop the direct combustion technology in the recent years. There is lack of the experience in biomass power technology application, except a few biomass gasification technologies for generation electricity in the stage of demonstration. In short, the category of mature biomass power technology isn't abundant, holistic research isn't good enough.

4.2 Economic barriers

The economic is another barrier restricting industrialization of biomass power. The major restricting factors are lacking investment and raising money hard. The biomass power project has the characteristics of small scale, relatively high cost and low density of capital. The investors invest with discretion, considering decentralization of capital and difficulty of management. The investment of medium-small scaled biomass power projects was on the order of 1 to 10 million RMB yuan. It is still difficult for medium-small scaled enterprises to complete the projects, especially the enterprises in the rural areas. Biomass power is full of investment risk and not completely understood, thus it is difficult to get a bank loan presently.

4.3 Policy barriers

Chinese government constitutes some sustaining policies on renewable energy, and the policies are ambiguous and hard to execute for local government. The sustaining policies are mainly instructional and not imperative, lacking of economic encourage. The preferential price of electricity generated from renewable energy is the cost of economic benefits of local power grid. It directly affects the positivity of local government developing renewable energy, due to lacks of subsidies.

4.4 Policy demand of biomass power technology development in China

Renewable energy power technology is obviously restricted by policies and social accepting degree whose impact on biomass power project is evident. This is because that most people consider biomass as conventional energy and some local governments don't know the preferential policy. Another reason is that most biomass power projects are small, even smaller than wind power station, and every biomass power station(less than 1000kW) has to pass a series of examining and approving procedures, including project, feasibility and preferential price, that affects the positivity of social investment. To expand biomass power in force, Chinese government should constitute detailed sustaining policies that include:

4.4.1 Constitute programmed legislation

It demands for constituting easy-operating management procedure, making investors understand the demand and procedure of application.

4.4.2 Constitute canonical qualification authentication procedure

Because of the differences in materials, scale and technology, the technology parameter, capital and benefit are different. It's difficult to constitute simple standard for biomass power technology. It requests the government to constitute canonical qualification authentication procedure, considering impacts of environmental and social benefits. These canonical procedures will help gasification mixed combustion generation electricity technology to apply widely. The government hasn't to restrict and provide what technology investors choose.

4.4.3 Provide market condition of fair competition

The biomass power cost is decided by the technology and resource, higher than conventional power, even wind power cost in some areas. However it is suitable for rural areas, because it help increase production, provide country employment and develop local economy. For providing market condition of fair competition, the government should reflect in the round on social and environmental effects of biomass energy.

5. Conclusion

(1) Biomass resource is multiform, abundant. The biomass power technology has great potential of application and good development perspective.

(2) Currently agricultural residue is central part of biomass resource, owing to Chinese present economic status. Its characteristics are dispersed resource, high collection and transportation cost, great change with seasons and unstable provision.

(3) Biomass power technology is mature and applied broadly. Foreign direct combustion technology is successful, and China is good at gasification generation electricity. Restricted manufacture, throughput and lacking of experience in direct combustion technology, it need improve equipment production in order to reduce the investment cost.

(4) In the mass biomass power technology is affected easily and not economical, thus it is in need of special incentives to develop and popularize the technology.

(5) Considering economic status and biomass power technology in China, the government should provide advantaged condition on policy and pay attention to the diversification of technology and investment.

The Development Potential of Biofuel in China

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1. Liquid biofuel is a major focus of China's future plan for developing biomass energy.

1.1 The momentum for liquid biofuel Industry is to seek oil security.

Biomass Energy is an energy source derived from cereal stalks, agricultural waste, firewood, animal waste, organic industrial waste water and residue, city household garbage and energy plants. Biomass energy could turn into terminal energy sources like power, gas fuel, solid fuel and liquid fuel, among which, liquid biofuel receives the most attention. Many countries around the globe have already started developing a biofuel Industry(including production of liquid bio-fuel and relevant Industries, such as energy agriculture and forestry) for the purpose of securing oil safety.

In 2004, China consumed 0.31 billion tons of oil, among which 1.2 billion was imported, making up 38.7% of the total. IEA predicted that China would depend 61.0% of its oil supply from import by 2010, and 76.9% by 2020. China's sharp increase of oil import and its growing dependency on import pose potential threat to its oil security and raise concerns and worries among other countries. Could domestic oil production and alternative energy supply "feed China"? Compared with the limited coal liquefaction and natural gas exploitation, liquid biofuel, as a renewable and promising energy form, has drawn more and more attention. In 2002, Brazil fermented cane sugar to distillate ethanol and consumed 10.4 billion kilolitres of it, the substitute rate is close to 40%.

Though U.S. and European countries have gained much experience in developing liquid biofuel, Brazil's development course is more close to that of China. Brazil's liquid biofuel Industry ,which began from ethanol projects and then extended to bio-diesel , was set up in 1975 in order to:1). secure its energy safety and economic development: during the first oil crisis in 1973-1974, Brazil lost 4 billions dollars and its national economy suffered a heavy blow since 80% of its fuel supply depended on import then. 2). safeguard the development its plantations and protect farmers' interests, as Brazil has the world's largest sugar cane plantations.

1.2 Liquid biofuel Industry would bring environment benefits.

Large scale development of energy agriculture and forestry would effectively afforest barren lands and hills, reduce soil erosion and prevent water and soil lost. The use of liquid biofuel would have a positive influence on the protection and improvement of the atmosphere: compared with fossil fuels, the burning of liquid biofuel produces few air pollutants like NOx and SOx; as plants absorb and produce CO2 and thus form the carbon cycle, the discharge of CO2 by using liquid biofuel is significantly lower than normal fuels.

If liquid biofuel production could reach 0.105 billion ton by 2050(The statistic is based on the analysis of biomass energy in the research project "an anylysis on the mid and long term energy development and usage of China" published in 2005 by the Energy Research Institute. According to the analysis, energy forestry would mainly focus on raw materials for bio-diesel and energy agriculture on raw materials for ethanol. The estimated production of ethanol would be 3.9 ,7.3,16.0 million tons in 2020,2030,2050 respectively and that of bio-diesel 15,33,89 million tons), about 30 million hectare barren lands and hills could be reforested and the discharge of CO2 be reduced by 0.31 billion tons.

1.3 the development of liquid biofuel Industry would also help solve the rural problems.

Constructing an industrial chain from energy agriculture and forestry to the production of liquid biofuel would be an effective way to solve the rural problems existing in China.

1.3.1 drive the development of agriculture and forestry .

The estimated production of liquid biofuel in 2020 is around 19 million tons, which would help create production value of 100 billion yuan for central and regional governments according to preliminary calculation. If the liquid biofuel production could reach 0.105 billion tons by 2050, it could create production value of 500 billion yuan , employ more than 10 million workers (mainly for energy agriculture and forestry),and give great momentum to the rural economic development. The initial investment to reach this production scale (mostly on investment in Industrial development, the forestation of barren lands and hills ,and tree species) could be controlled within 1 trillion yuan. The ratio of annual production value against investment (1:2) is larger than that of some normal energy Industry sectors.(for instance, the ratio of annual production value against investment is approximately 1:1.25).

1.3.2 Create jobs, especially in the rural area.

The liquid biofuel Industry could employ more than 10 million workers. With the majority of them from rural areas, the Industry could help ease the condition of heavy unemployment in the rural areas.

1.3.3 Support the urbanization of China

On one hand, urbanization raises the per capita energy requirement, especially per capita requirement for fuel; on the other hand, urbanization require accompanying Industrial development and creation of job opportunities (to certain extent, more jobs need to be created in the rural areas to cushion the huge migrating crowd into the towns): energy agriculture and forestry would play an important role in both sectors.

2. The current situation and development trend of China's liquid biofuel Industry

2.1 China has the basic technology to develop the liquid biofuel Industry.

The key technology of liquid biofuel Industry is the liquid biofuel technology and the technique of breeding selections and planting the energy plants. Since the Eighth 5 year Plan, China has been carrying out researches on liquid biofuel transition technology, using traditional methods to produce alcohols and oil products from crops and oil plants, which is only limited to food and light Industry. Producing fuels for transportation energy started when the former State planning Commission announced and implemented it during the "ninth 5 year plan" period. Energy plant is a new word in China. But researches on the breeding selection and planting technology have been going on for years.

2.1.1 Producing liquid biofuel from deteriorative grain

Currently, liquid biofuel is largely produced from deteriorative grain in China. Strictly speaking, producing ethanol from deteriorative grain is not energy agriculture, for grain plants and energy plants have every distinct difference in their usage. However, this technology have helped to accumulate experience and laid the foundation for the liquid biofuel Industry. When sorgo and other energy plants are planted in large scales, the Industry could turn to these new raw materials.

Approved by the State Council, the Former National Planning Commission announced to add ethanol in motor petrol in China. At the same time, The State Bureau of Quality and Technical Supervision announced two national standards :"Denatured fuel ethanol" and "Ethanol gasoline for motor vehicles". The government invested more than 5 billion yuan, approved to set up 4 fuel ethanol Production Company to get rid of "deteriorative grain". Now the companies are put into production and have an annul production capacity of 1 million tons. The cost of producing ethanol from grain is 3000 yuan per ton, added with the production cost; the cost for producing ethanol is 4000 yuan per ton.

The State government have ordered Heilongjiang ,Jilin ,Liaoning, Henan, Anhui, and part of Hubei, Shangdong, Hebei and Jiangsu to enforce the use of ethanol gasoline for motor vehicles. Till 2005, all the cars in the above mentioned provinces and their governing cities have to use ethanol gasoline, military and special reserves excluded.

2.1.2 Energy plants: sorgo and sugar cane

Thanks to the research program “ producing fuel ethanol from sorgo stalk” supported by the “863 Plan” of the ministry of Science and Technology, the sorgo species ,the planting techniques and the production technology are mature. Now the country has an annul production of fuel ethanol of 5000 ton. Sorgo plantations have been set up in Heilongjiang, the Inner Mongolia Autonomous Region, Xinjiang Uygur Autonomous Region, Liangning and Shandong, to produce fuel ethanol. To cost for purchasing sorgo stalks is 2000 yuan for one ton of fuel ethanol, added with production cost, the production cost of fuel ethanol is 3500 per ton. To produce a ton of fuel ethanol requires 16 tons of sorgo stalks (the average output of 4 mou in northern China). The waste could produce 500 kilos of bio-diesel. The ethanol production only uses sorgo’s stalk, its seeds could still serve as grain.(not used to ferment to produce ethanol) .The sorgo plant is suitable to plant in any place where temperature is above 10 and effective accumulated temperature above 2000. Compared to other plants, sorgo is more capable of eduring drought and lodgement of water ,as well as adjusting to alkaline lands.

Sugar cane is an important sugar plant in China. In recent years, sugar cane plantations have played an important role in lifting out poverty in Guangxi, Yunnan and Guizhou provinces. However, the demand for sugar is limited and as a result of the introduction of Sweet flavors, there have been large fluctuations of planting areas. However, there is a huge demand for fuel ethanol, making Southern China the favorite place for mass producing raw materials for fuel ethanol. Approximately 4 mou’s output of sugar cane is required to produce a ton of ethanol, almost the same as sorgo. The production waste could also used to produce bio-diesel.

2.1.3 Energy plants: Barbadosnut and Pistacia lentiscus

China has made achievement in the research of forest plants. It has developed an industry in the southern part of China. Many cases of producing bio-diesel oil from colza oil, cottonseed oil, woodoil, Chinese tallow oil, tea oil in miniature occur in these areas. In recent years, China has developed new technology of producing bio-diesel oil from seeds to avoid the competition for raw material with oil and industry oil, which primarily can be commercialized. Sichuan province sets up a bio-diesel oil factory whose capacity reaches one hundred thousand tons. It can produce 20000 ton at present and set up the product standards. The price of raw material is the main factor the limitation of the technology. The price of barbadosnut seeds is 1.4 Yuan per 500 gram, while every ton of bio-diesel oil needs more than three tons barbadosnut and cost more than 4000yuan. The amount of bio-diesel oil which was made from per acre of area of barbadosnut can reach 200kg.the oil percentage of Pistacia lentiscus is about 30%. On condition that 40 Pistacia lentiscus grow in per acre of area and every Pistacia lentiscus can produce 20 kg seeds, the amount of bio-diesel oil which was made from per acre of area of Pistacia lentiscus is also 200kg.Both barbadosnut and Pistacia lentiscus can grow in rather wide area in China. With the development of relevant research, it is absolutely possible that similar or more productive adoptable species can be discovered or cultivated. (Including the ameliorative species of barbadosnut and Pistacia lentiscus)

2.1.4 Economic benefits of the bio-oil industry

Take raw material of grain alcohol, sweet sorghum bicolorthe, for example. According to the experience in Inner Mongolia, per acre of sweet sorghum bicolorthe can bring 140 Yuan more than common corn. (Chart 1)

Table 1 benefits of sweet sorghum compared with corn:

unit/Yuan	Per acre income of sweet sorghum bicolorthe	Per acre income of corn	Note
Seeds	400	500	The cost is similar
Haulm	240	0	The corn haulm will be burnt directly, while the sweet sorghum haulm will be sold to the alcohol factory.
Total	640	500	

To plant barbadosnut tree also bring more benefits: even at the low productivity, 450 kg per acre, it brings 630 Yuan per acre.

At present, the cost of biofuel is high than fossil fuel, but the technological innovation has great potential to reduce cost. Take Brazil as an example, the production cost of ethanol has been reduced to 300 dollars from 800. In addition, because fossil fuel reservs are limited,the price will continue to rise.In comparison,biofuel has a relatively competitive price advantage.

2.2 The currect scale of biofuel industry and product price in China

China’s bio-diesel industry is now in its preliminary stage, with an annul production capacity of less than 30 thousand tons,but it has a bright future.Relevant information is available in table 2,3,4. (reference：Liu shunde，professor in college of chemistry in tsinghua university)

Table 2 the current situation of biofuel industry in China:

corporation	Starting time	Designed capacity	Current capacity	Raw material	techniques	operating costs	market
Zhuoyue new energy cooperation in Longyan	Nov in 2001	20,000 tons	20,000 tons	Waste oil(all over China)	Solid acid catalysis craft developed by themselves）	Process cost 800RMB/ton(raw material not included）	Price 4250RMB/ton；sell to the local gas station or consumers
Gushan grease chemistry cooperation in Sichuan	2000	10,000 ton	Less than 5000 ton	Waste oil	chemistry alkali catalyzes	NA	NA
Zhenghe cooperation in Hainan	2000	10,000 ton	NA	oil wood	chemistry alkali catalyzes	No product sells	—

Table 3 completed mid scale experiment:

corporation	Starting time	Designed capacity	Current Capacity	Raw material	techniques	operating costs
Broad bioengineering corporation in Hunan	2004-2005	200 Kg/day	200Kg/day	colza oil	Biology enzyme craft of chemistry department in tsinghua university	Process cost 800RMB/ton(raw material not included）

Table 4 some of currently planned commercialized program:

corporation	Starting time	Designed capacity	Raw material	techniques	operating costs	market
Hongchang group in xinyang,Henan	2006	30,000in 2006；100,000in 2010；300,000in 2015	Local oilwood（Chinese tallow oil、waste oil allover china）etc	Biology enzyme craft of chemistry department in tsinghua university	Process cost 700-800RMB/ton(raw material not included）	sell to the gas station all over China or consumers
Broad bioengineering corporation in Hunan	2006年	100000 tons	Waste iol	Biology enzyme craft of chemistry department in Tsinghua university	Process cost 700-800RMB/ton(raw material not included）	Gas station and local bus

Anhui province became the fifth pilot province for grain alcohol after Heilongjiang, Jilin, Liaoning, Henan in april1st, 2005. The capacity of alcohol fuel can reach 860000 ton per year. (Chart 5). Anhui Fengyuan group is building devices for alcohol fuel with a capacity of 200000 tons, which can produce alcohol fuel in this year and China's capacity of alcohol fuel will reach 1020000 tons per year. Alcohol fuel sells at the price of gasoline’s price multiplied 0.911. The government will provide allowance to cover the margins.

Table 5 distribution of raw material of alcohol fuel and capacity:

	Capacity （10 thousand tons/year）	Raw materials	Capacity of Raw material （10 thousand tons/year）
Jilin	30	Corn	99
Heilongjiang	10	Corn	33
Henna	30	Wheat/ Tapioca	90
Anhui	12	corn	36

2.3 The potential and future of the biofuel in China

2.3.1 China has great space for the development of biofuel

The resource potential is mainly determined by the acreage of suitable area for energy plants and the productivity of per acre. The soil resources available for energy agriculture is sufficient :9470000 hectares area suitable for farming, at the percentage of 60% ;there are 722 400 hectares area for sorghum bicolorthe in 2003, at the percentage 80% of promotion of sweet sorgum bicolorthe; among 8000000 hectares salty alkaline area, about 1670000 hectares has been alliterated ,at the percentage of 80% ,7596000 hectares area can be used in the energy agriculture in total. As to grow sweet sorghum bicolorthe(the output of biofuel is similar to common sugarcane), it can produce about 285000000 tons bio- alcohol and 14250000 tons of bio-diesel oil. All the area mentioned above is not conflicted with the planned agricultural. According to the long term prediction of the food supplies, the field needn’t increase, for the growth of potential per acre.

Excluding the land used for energy agriculture ,the usable land resources for energy forestry include: 60% of the 57 million hectares non-stocked land(some are used to develop commercial forest); 80% of the 14.7 million hectares land afforested from farm land(Some of the land is used as orchard .Considering the limited demand for fruit and that China has 2.12 million hectares reserve land for orchard, the percentage is relatively high), and 40% of the 53.93 million hectares barren land and hills suitable for forestry. In total, the land for energy forestry is 67.53 million hectares. If we plant the mastic tree on all the land, 202.6 million tons of bio-diesel could be produced. Referring to the mid and long term forestry plan of China, the above usage of land for energy forestry has few conflicts with that plan.

Energy agriculture and forestry has potentials. Firstly, China need to properly use its current cultivated land, forest land and cultivated land reserves(55.2million hectares, about 14% of the total cultivated land and forest land).Secondly, barren land and hills(21.6 million hectares, 40% of the total barren land and hills) need to be properly developed. Thirdly, some Salinized cultivated land could also be reshaped and reused. (13 million hectares, 17% of the total Salinized land). All together, the total amount of land for energy agriculture and forestry is 78 million hectares (China has 130 million cultivated land and 260 forest land). These land resources could serve as a solid basis for the raw materials required by biofuel Industry.

In addition, research and technology are carving out new energy resources. Algae is rich in biomass and once algae species with high oil content are developed and Industrialized, tens of millions of bio-diesel could be produced, for China has 50 million mou of coastal shallow land and inland water area. Using modern bio technology like genetic project, the US National Renewable Energy Laboratory has breeded algae with 60% of oil content, capable of producing more than 2 tons of bio-diesel per mou. In the past 2 decades, Ocean University of Qingdao has carried out more than 30 provincial and state biotechnology researches on algae breeding selections, and has accumulated valuable experience on algae research and breeding. If we could combine modern biotechnology and traditional breeding selections method together, optimize breeding conditions, it is possible to plant high oil content algae in large scales.

2.3.2 Predictions on China's biofuel practical development

In the passages above, we analyzed the potential of biofuel from the resources potential, but its practical development relies on many complicated factors, mainly:

1) Demand. China's oil supply would be stressful. Oil from Domestic production, foreign import and liquidation of coal is limited, which provides a good opportunity for the development of biofuel Industry.

2) Economical efficiency. The economical efficiency of liquid biofuel depends on the maturity of the technology, cost reduction resulted from scale production, and the oil price.(Now little of the internalization of environmental cost is considered) The price oil might fluctuate and remain uncertain in a short period ,but in the long run, the rising trend is quite obvious. Compared to crude oil, as the technology matures and production scale increases, the cost of liquid biofuel would decrease continually and thus increase its competitive power.

3) Integrity. On one hand ,an important part of the core technology of Liquid biofuel project lies in research and technology. It is a typical energy project that requires scale and time(So an energy plan is required): if is to use Saline land or barren land, the time required to reshape the land has to be considered, and in energy forestry, there is

a growing period for trees. On the other hand, the raw materials are from agriculture and forestry. Whether China can smoothly and coordinately develop its liquid biofuel Industry or not largely depends on the integration of energy ,agriculture and forestry deparments. Take US as an example, both its energy ministry and agriculture ministry has an energy agriculture project and the two ministries have maintained good cooperation and communication.

4) Policies. On one hand, liquid biofuel has its significant energy, environmental and social benefits, and should be supported by policies. On the other hand, the central government has strict plans for the usage of land. The required land for energy agriculture and forestry should be included in the land usage plan.

Based on these analysis, one situation for the liquid biofuel development is: in 2010, annual liquid biofuel production is 6 million tons ,with production value at 24 billion yuan, among which, ethanol(Ethanol gasoline for motor vehicles)production is 5 millions tons and bio-diesel 1 million. In 2020, annual liquid biofuel production is 19 million tons, with production value at 100 billion yuan, among which, ethanol production is 10 million tons and bio-diesel 9 millions.

3. Discussions on the China's development strategy of liquid biofuel.

3.1 The "State invest at the initial stage , corporations and research institutions be the major force" research and development strategy.

The maturity and economic beneficiary of technology is of vital importance for renewable energy Industries. Many countries have accumulated experience in the research and development of renewable energies, especially the US. America's key strategy for renewable energy development has been consistent and precise: Government invest at the initial stage, attract Industry community to participate in research and development of key technologies that might be of great importantce in the long run (20 or even 50 years later), accelerate the commercialization of the technology and develop the related equipment manufacturing system. The U.S government encourages corporations to secure the country's top position in renewable energy technology, and it has established and is going to establish a series of policies and pass laws to promote the development biomass energy technology and its commercialization , for instance " the biomass research and development act of 2000".

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To secure the development and promotion of biomass research, the U.S. Department of Energy has decided to invest 5 million dollars research fund to attract relative companies and institutions to apply for its laid out projects. Currently there is a popular trend for biomass research and many institutions participated in the project. To seek more research fund, the U.S government promoted the purchase of renewable energy credit card.

The US has also taken measures to directly inspire consumers and researchers. For instance, in July, 2003, US Department of Agriculture appropriated 0.77 million dollars to National Bio-diesel Board, entrusting it to start the Bio-diesel Education Program, and at the same time, appropriated 0.19 million dollars to honor researchers in Idaho University for their outing standing contributions in bio-diesel research.

Learning from American experience, it is important for the government to invest at the initial stage(especially concerning Chinese government's tight control over the energy and agriculture departments) so that : sufficient funds could be secured for key technology development ; competitive or related technologies could be reviewed and develop within a systematic frame equally.

The "based on the market mechanism, with the necessary policy support "Industrial development strategy.

Energy agriculture and forestry, liquid biofuel manufacture Industry have significant energy, social, and environmental benefits, and should be supported by government policies, such as tax reductions and discount government loans. These are critical for new and developing Industries. China has already passed the ,like the , their articles supporting renewable and clean energy are mostly principle. More precise and concrete regulations need to be made. Besides, monopoly still exist in the Chinese petrol Industry which prevents the liquid biofuel from a quick entry into the market. These problems need to be addressed by government policies.

The main reason that American's bio-diesel Industry falls behind the EU is that its stimulation policies has fallen behind. At the end of 2004, Bio-diesel production increased dramatically when President Bush signed the Federal corporation tax act that included favorable policies for the bio-diesel Industry.

In the long run, a market competition system is of fundamental importance to reduce cost and enhance competitive power.(see Chart 1)

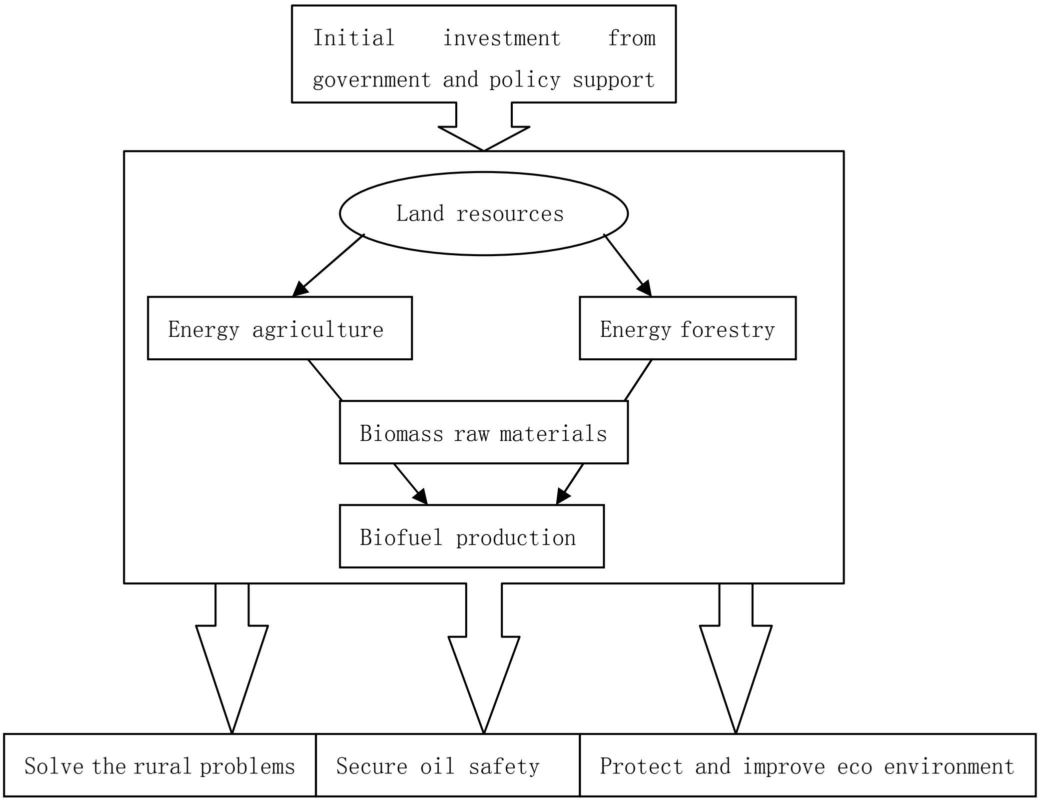

Chart 1 energy foresty sturcture and benefits:

In fact, economical benefit is the best stimulation for energy agriculture and forestry. For instance, on June 17th ,2005, Guangxi Wanjia Sugar Corporation signed a contract with Youjiang District government of Baise County ,Guangxi province. According to the contract, 500 million yuan was invested to build a sugar factory with a daily production of 5000 tons and a fuel ethanol factory with an annul production of 300 thousand tons. Encouraging producing ethanol form sugar cane has several advantages: 1. Since large sugar factories have alcohol workshops, the cost of increasing production is only 1000 yuan per ton , much less than normal ethanol projects (4000 yuan per ton); 2. the production cost of ethanol is less than 3000 yuan per ton, manufacture cost included. If it is put into large scale production, the profit return is even more favorable. 3. Farmers are also stimulated since they could get 400 more per mou by planting energy sugar canes instead of current varieties. 4. Waste water from ethanol production used to be a problem, now however, with the development of pollution control technology, it could be reused and make profits. When the amount of CODcx in waste water is above 40,000 mg/L, the investment on pollution control could be taken back in five years.

3.3 Implement the land strategy of “use little or no cultivated land, make full use of forest land and barren land”

Though cultivated land in China still has potential to increase yield, large scale energy agriculture and forestry needs to rely on the vast non-stocked land and undeveloped land usable for forestation. In fact, most of China's land usable for forestation is located at places with convenient communication and abundant labor. According to experts, the obstacle for fast forestation in these areas is mainly institutional(economic concern is not the only factor), such as the refinement of propriety right of forest.

Combining forestry and energy supply has great significance in driving the forestry Industry and increasing oil supply. It is worthwhile to mention the determination of Indian government to develop energy forestry. Indian Prime minister was quoted as saying, "if we can start the program to produce bio-diesel from the seeds of pistacia, 36 million jobs would be created and 33 million hectares of barren and dry land could be turned into oil fields."

To develop energy agriculture and forestry practically, further surveys need to be done to draw a reasonable plan on the use of land resources. At present, the State Forestry Administration is beginning to realize the development potential of energy forestry and preliminary surveys have been carried out.

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Biogas Resources of China and Its Exploitation and Utilization

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1. China is abundant in biogas resources.

In China, the exploitation and utilization of biogas mainly adopt anaerobic process technology which processes pollution of organic wastes from industry and agriculture, municipal solid waste and municipal sewage. So, the research of this thesis is about pollution of organic wastes from industry, excrements pollution from livestock and poultry farming, municipal solid waste, municipal sewage and excrements from household livestock and poultry.

1.1 The annual industrial discharge in China amounts to 2.5 billion t for organic wastewater and 70 million t for residue in 2002.

The sources of industrial organic wastes are from light industrial enterprise and the non-light industrial enterprise. The light industrial productions, which are producers of organic wastes, are the following over 10 industrial sectors, such as alcohol, sugar, beer, rice wine, distilled spirit, starch, monosodium glutamate, beverage, pulp & paper etc. The annual waste discharge is 846 million t for organic wastewater and 24.44 million t for residue a year. The main producers in non-light industry which discharge organic wastes are the following sectors, such as pharmacy, slaughter, flour, vegetable oil, soy sauce, food can, petrochemical products, crude rubber, furfural etc. According to statistics, the annual waste discharge is 1.67385 billion t for organic wastewater and 49.3402 million t for residue.

Based on the current national discharge of industrial organic wastewater (which can be converted into biogas) of 2.52 billion t/y, and the residue of 73 million t/y, these wastes can be converted into 10.68 billion m^3 biogas (56% methane content) by anaerobic digestion treatment.

Based on the quantity of biogas output per m^3 effluent, the industrial productions, which are producers of organic wastes, can be divided into 3 parts. Part 1: More than 10 m^3 biogas per m^3 effluent. The main industrial sectors include alcohol, distilled spirit, starch, monosodium glutamate, acetic acid, yeast, semi-chemical and mechanical pulp. Part 2: about 5-10 m^3 biogas per m^3 effluent. It Include the enzyme product, pharmacy, fiber plate and the vegetable oil. Part 3: less than 5 m^3 biogas per m^3 effluent, it Including sugar, beer, rice wine, juice beverage, slaughter, flour, meat can, PTA, furfural. Although Part 1 only accounts for 15% the total wastewater or so, from the viewpoint of biogas resource, it accounts for nearly 60% the total biogas resource.

In consideration of the sustained development of national economy, the long-term plan of China national economy of 2020 estimates that the total economy of china will be increased by four times of that in 2000. Based on the estimation, the total newly added production value of the industry will be also increased by four times of that in 2000, while the discharge of industrial organic wastewater (residue) will be doubled as a whole by then. Thus the resources which can be converted into biogas will in turn double that in 2000, amounting to about 2.15 billion m^3.

1.2 The annual excrements discharge in China amounts to 1.8 billion t.

According to China Livestock Husbandry Yearbook 2003 and the calculation on the in-pen number of swine, poultry and cattle, the total annual excrements discharge from livestock and poultry farms has been up to 1.8 billion t. If the washing water from scale production is taken into consideration, the actual total sewage discharge far exceeds 20 billion t. Based on production potential of excrement sources producing biogas, we can get more than 70 billion m^3 biogas from these excrement sources.

There are two approaches to produce biogas from excrements. One is the scale livestock and poultry farm, it gets biogas through treating its excrements by adopting biogas project technology. There were totally 8,241 scale livestock and poultry farms (they had more than 3000 pigs) nationwide in 2002, the annual excrements discharge is totally about 49 million t and 2.72 billion m^3 of biogas can be produced from these excrements. In addition, the total annual excrements discharge from small sized livestock and poultry farms (they had 500-3000 pigs) were 85 million t. Because of the difficulty of collection and management, the production potential of these excrement sources is about 1.23 billion m^3 biogas.

The other one is household biogas digester which is widely popularized in rural area of China. If a household has more than 4 pigs, it can build a 6-10 m^3 biogas digester which can produce 300 m^3 of biogas per year. The total of household livestock and poultry is very lager, biogas resources can up to 60 billion m^3, but the collection excrements and technology management is difficult, the actual production from these excrement sources is only about 15-20 billion m^3 biogas.

According to the livestock husbandry development plan, by 2010, the livestock and poultry farming will be increased by about 8% every year. From 2010-2020, it will be increased by about 3-5% every year. Therefore, by 2020, the biogas resource from excrements will be about 3 times that in 2002. The scale livestock and poultry farm will rapidly develop while the economy of china keeps increasing, if calculating by 5% rate, the biogas resources from the scale livestock and poultry farm (also including the small scale ones) will be 15-20 billion m^3, and 30 billion m^3 from household.

1.3 Municipal sewage and solid waste.

In 2003, the municipal solid wastes which had been disposed were 149 million t, and the municipal sewage was 24.7 billion t. If 50% of these wastes were used to produce biogas through sanitary land fill technology, the biogas resources from this would be 9 billion m^3; if 30%-40% of this sewage were used to produce biogas, the biogas resources would be 1 billion m^3, so, the total would be 10 billion m^3.

According to the city development plan of China, the municipal solid wastes and sewage will increase more than 100% by 2020, the biogas resources from these will be up to 20 billion m^3.

1.4 The total gettable biogas resources are 44.6 billion m^3 at present.

All the above dates are collected into table 1. It shows that the total gettable biogas resources are 44.6 billion m^3 at present in China. If calculated by heat equivalent (23.02 million J/ m^3), this biogas is equivalent to 35 million tons of coal equivalent, and it can substitute for 5 million tons of coal (20.93 million J/ m^3).

Except for household biogas, all the biogas resources mentioned can be used for generating electricity, and the total is 24.6 billion m^3. With the current technical level in China, 1 m^3 biogas can generate electricity 1.6 kWh, so the total quantity of electricity is 39.4 TWh, with installed capacity of 6.56 GW (based on the calculation of power generation 6000 hours/y).

By 2020, the biogas resources of china will be u to 91.5 billion m^3, and they are 2 times that in 2000, equivalent to 71.9 million tons of coal equivalent. If be exploited and used, these resources are equivalent to 100 million tons of coal, which are very valuable energy resources. Except for 30 billion m^3 of household biogas, there still is 61.5 billion m^3 of biogas which can generate electricity 123 TWh (1 m^3 biogas can generate electricity 2 kWh), with installed capacity of 20.5 GW, equivalent to five larger nuclear power plants (each plants is 4 GW).

Table 1 Summary of Nationwide Biogas Resources

The Section	Now		In 2020	
	Biogas (billion m^3)	Coal equivalent (million tce)	Biogas (billion m^3)	Coal equivalent (million tce)
Industrial organic waste [1]	10.6	8.33	21.5	16.89
Livestock and poultry farms [1]	4	3.14	20	15.71
Household biogas[1]	~20[2]	15.70	30	23.57
Municipal solid waste and sewage [3]	~10	7.86	20	15.71
The total	44.6	35.03	91.5	71.88

Data source:

[1] Research report: National Action Plan for Industrial Scale Biogas Development, date in 2003, 2004

[2] Biogas resource was 70 billion m^3; the date in the table has been converted because of the in influence of tech, collection and management.

[3] China statistical yearbook 2004, China Statistics Press, 2005.

2. Current situation of biogas technology and its development.

2.1 Biogas project technology has been basically in maturity and the fermentation processes are mainly concentrated on UASB and CSTR

After its development for 20 years, the process technology for large and medium-sized biogas project in China has been basically in maturity. The currently adopted techniques have been successfully used for the treatment of various kinds of organic wastewater. In the existing biogas projects for industrial organic wastes, UASB and CSTR account for 80% (see Table 2). The technical characteristics of various processes can be seen in Table 3.

Table 2 Biogas Fermentation Processes for Industrial Organic Wastewater

	Type	Number*	Percentage
1	UASB	200	49.26
2	CSTR	128	31.53
3	EGSB	14	3.45
4	IC	30	7.39
5	AF	8	1.97
6	UBF	5	1.23
7	Others	21	5.15
		406	100

* Data of 2000. CSTR+UASB are included in CSTR.

For UASB-Upper-flow Anaerobic Sludge Blanket reactor, its characteristics are: Due to cultivated granular sludge, the anaerobic microbial species would not be lost; it greatly enhances the anaerobic fermentation efficiency. In addition it does not need agitation, it is simple in operation, adapting to both high and low concentration of COD load and covering less land. So it is extensively applied (accounting for 49.26% of the total projects) in our country. The biggest UASB anaerobic project was set up in Fangting Distillery, in Xuzhou, Jiangsu Province. The total volume of the tank group amounts to 10,000 m^3. The biggest single unit volume of UASB in China has been up to 4,000 m^3.

For CSTR-Completely Stirred Tank Reactor with anaerobic process, it is suitable for wastewater with high suspended matter and high concentration (high temperature). It is mostly applied in the treatment of alcohol lees liquor. The biggest CSTR anaerobic tank group for this kind of wastewater was set up and put into operation in 1999 in Xintai Alcohol Company in Taicang, Jiangsu Province. The total volume of the tank group amounts to 13,200 m^3, with a treatment capacity of nearly 2,000 m^3 of dried cassava wastewater per day and biogas output over 40,000 m^3/d. The biggest single unit volume of 5,000 m^3 was set up in Nanyang Alcohol Distillery in Henan Province.

Table 3 Technical Characteristics of Various Kinds of Fermentation Processes

Type / Index		Common digestion pond	CSTR	UASB	IC	UFB
1	Organic load (Kg COD/ m^3.d)	< 3.0	5.0-10.0	8.0-15.0	15-30	15-30
2	Allowable organic suspended matter content for influent	up to 50 g/ l	up to 50 g/ l	Generally <4 g/ l	<1.5g/l	<1.5g/l
3	COD removal	lower	medium	higher	higher	higher
4	Hydraulic retention	15	4-10	1-10	0.5-4	0.5-3
5	Power consumption	bigger	bigger	smaller	small	smaller
6	Production control	easier	easier	more difficult	more difficult	difficult
7	Investment	higher	medium	smaller	higher	higher
8	Land coverage	bigger	medium	smaller	small	small
9	Production experience	a little	more	more	less	less
10	Operation cost	low	low	low	medium	medium

Note: Both IC and UFB belong to one of the types of EGSB.1

In resent years, new high-effective IC and EGSB anaerobic equipment have been applied more extensively. This kind of equipment is high in efficiency and small in land coverage. It is especially suitable for wastewater with low suspended solid and low concentration (such as paper, beer and starch wastewater).

2.2 The auxiliary technology of the biogas project has been developed

In the last 10 years, the Chinese technicians have done a lot for the standardized and serial design and industrialized development for the most utilized complete stirred anaerobic fermentation tank and UASB reactor. They have completed the serial design of the tank body of complete stirred anaerobic fermentation tank and its internal jet pump stirrer and biogas stirrer. Concerning the UASB tank structure,

three-phase separator and water distribution system etc., the standardized design of two big series has been formed, i.e. rectangular reactor and round UASB reactor.
At the same time, the foreign new material and new technology have been imported for the design and manufacture, such as the double-folded side biting technology of Lipp Company and assemble tank-making technology of Farmetic Company in Germany. The period of project construction is shorted due to the on-site assemblage, and thus it can save over 50% of material compared with normal steel. Furthermore it has the advantages of anticorrosion, advanced technology and good performance. At present, these technologies have been greatly expanded and tens sets of equipment have been set up in China.

In the research and development of auxiliary equipment of biogas project, a certain technical level has been achieved, there are different types of products on the market and used for various biogas projects, including:

(1) The solid-liquid separator is used widely. In order to adapt to the requirement for the separation machinery in comprehensive utilization, or fermentation and post-treatment processes, the technicians have developed in recent years some separation machines which tally with the characteristics of biogas project, such as vibration screen, slant plate screen, rotary screen, fixed bed filtration screen etc., and some others machines for complex precipitation and press. The dewatering rate is generally 10-40%, basically meet the requirement for process and comprehensive utilization.

(2) The quality of transportation device for stock liquor is reliable. In recent years, in accordance with the characteristics of the variety and different physical and chemical properties of biogas stock liquor, many kinds of transportation devices for livestock and poultry excrements are developed one after another successfully, of which the efficiency of 75Y E-10 pump developed by Shanghai itself is up to about 65%, its performance is even better than that of the same kind product developed by foreign country.

(3) The devices for biogas purification, storage and transportation are further developed. Some practical desulfation technologies have been developed and the desulfation effect can reach the standard for H2S content of coal gas in the city. The wet type steel gas storage tank is widely adopted for biogas storage. As for the biogas transportation of the dry type storage tank, the special biogas compressor is developed as the booster, in addition to Roots blower, air compressor, N and H gas compressor. There are also varieties of materials for the transportation pipeline, the replacement of steel with plastics and cast has been realized in some projects. In the same time, the research and development of the biogas utilization devices have gained a new progress, such as gas boiler, giant cooking utensils and biogas power-generating set.

2.3 Various suitable modes have been developed for biogas project

In practical construction, in terms of on-the–spot conditions, different forms and demands for treatment and comprehensive utilization of the fermented residue, the biogas projects can be classified into two types, i.e. ecological type and environmental type.

Ecological type biogas project, i.e. the fermented residue and waste liquor can be completely consumed by the farmland, fish ponds, plants ponds etc. around the biogas project, so that the biogas project can become the link of the agricultural ecological garden area. If the biogas project is targeted on the excrements from livestock and poultry, the first thing which should be done is the reasonable disposal of the feeding and planting. By this doing, it not only saves the high expenses on the post-treatment, but also enhances the agricultural ecological construction. The characteristics of this kind of project are easy post-treatment and lower investment and operation cost.

The environmental type biogas project is suitable for the following situations: the environment couldn't consume the fermented residue and waste liquor; the biogas residue should be turned into market fertilizer and the effluent is up to the discharge standard after post-treatment. In this mode, the resource could not be fully utilized and the costs of the project and its operation are relatively high.

China has developed various modes for biogas projects which are the scale livestock and poultry farm projects. One is comprehensive utilization type: all the excrements sewage can enter into the anaerobic treatment system; its process is very simple and easy to operate, and also it needs low investment and operation cost. Certainly, there are also shortcomings in this project. For example, its wastewater is still higher concentration after treatment and easy pollution on environment if without further treatment. In another type, all the excrements sewage is separated dry from the wet. The solid excrements are directly used for organic fertilizer production, while the washing sewage and urine get into the treatment system to produce biogas liquid. This liquid can be completely consumed by natural ecological environment, and also can be treated with aerobic treatment system in order to meet discharge standard.

2.4 The Household biogas.

The household biogas system is one type of China rural energy utilization. It includes the raw material processing, biogas digester, transportation, distribution, and utilization of the residue (solid waste and waste liquid). Generally, the area of household biogas digester is 6-9 m^3. Its raw materials are excrements of pigs, cattle, poultry and human, if there are only pigs, 4 are enough; its output is 250-400 m^3 per year. The technology of household biogas has been in maturity, so it is becoming more and more industrial.

2.5 The annual quantity of exploited and used biogas is 6.7 billion m^3.

Up to 2003, there were 600 biogas projects for industrial organic wastewater nationwide which have their anaerobic equipment, and the total volume of anaerobic digester is roughly 1.5 million m^3, whereas the treated organic wastewater was about 150 million t, only 4% of the total which should be treated. The annual biogas production is 1 billion m^3. These projects are distributed in 18 provinces, cities and regions including Shandong, Sichuan, Jiangsu etc., of them 105 in Shandong, accounting for 25.9%.

According to the statistics of MOA, there have been 2492 biogas projects for lager and medium scale livestock and poultry farms nationwide by 2004. The total volume of digester is roughly 2.2 million m^3, and the output of biogas was 89 million m^3 per year. These projects are distributed in 24 provinces, cities and regions, and more than 200 located in each province of Fujian, Zhejiang, Jiangxi, Hunan.

Up to 2004, there were 15.41 million household biogas digesters, and the output of biogas was 5.568 billion m^3 per year.

The projects which treat municipal sewage and solid waste with organic system are under experiment. At present, there are more than 100 demonstration projects in china.

Table 4 shows the state of China biogas exploitation and utilization. The quantity of exploited and used biogas was 6.657 billion m^3 in 2004. If calculated by heat equivalent, this biogas was equivalent to 5.23 million tons of coal equivalent, and it can substitute for 7.32 million tons of coal.

2.6 The quantity of exploited and used biogas will become 27 billion m^3 in 2020.

The exploitation and utilization of biogas project can treat the environmental pollution; be helpful for developing recycling economy and resource utilization integrated, and produce clean energy, so, the government has been paying more and more attention on it. China Renewable Energy Law will be implemented from Jan 1, 2006, and we believe that this event will greatly promote the development of the biogas exploitation and utilization in the future 15 years. Table 4 shows one scenario of China biogas exploitation and utilization in 2010 and 2020. From these dates, we can know that the quantity of exploited biogas will be 27 billion m^3 in 2020, which is about four times that in 2000, equivalent to 21.22 million tons of coal equivalent and substitute for 30 million tons of coal. It will keep increasing at the rate of 9.1%, which is greatly exceeded the development rate of fossil energy.

Table 4 The Exploitation and Utilization of China Biogas

	2004			2010			2020		
	Projects	Biogas (billion m^3)	Coal equivalent (million tce)	Projects	Biogas (billion m^3)	Coal equivalent (million tce)	Projects	Biogas (billion m^3)	Coal equivalent (million tce)
Industrial organic wastewater	600[1]	1	0.79	2000	4	3.14	5000	6	4.72
livestock and poultry farms	2492	0.089	0.07	10000	2	1.57	20000	4	3.14
Household biogas	15.41 million	5.568	4.37	3000 million	9	7.07	5000 million	15	11.79
Municipal sewage and solid waste	Under experiment	-	-	1000	1	0.79	2000	2	1.57
The total		6.657	5.23		16	12.57		27	21.22

Note：[1] Date in 2003

[2] The coefficient of biogas converted into coal equivalent is 0.7857

3. Main barriers in current biogas development.

In the last more than 20 years, the biogas project in our country has made a certain development. It has been technically mature and practical; also there have been a certain number of larger and medium scale biogas projects; the manufacturers and constructors are in initial scale. However on the whole, there is a lack of capacity for biogas industrial scale development. Because of the support from the government, which provide 1 billion national debts every year and each family can get several hundreds Yuan, more than 1million household biogas digesters are built every year. At the same time, the larger and medium scale biogas projects meet more trouble, the main problem are:

3.1 The biogas projects are lack in market competitiveness.

The initial investment for an industrial alcohol plant of 10,000 t is about 10 million Yuan (RMB), however in order to treat the organic wastewater, then its initial investment will be over 5 million Yuan. Likewise, the initial investment for a 10,000 pig farm is about 2 million Yuan (RMB), while initial investment for a biogas project of excrements sewage treatment will be over 1 million Yuan. That means if biogas projects are built together with their previous enterprises, the initial investment will increase over 50%. In addition the alcohol plants and livestock farms which are themselves the small-sized industries with meager profit and big risk, they are hardly to bear the financial pressures.

Table 5 shows us the unit output costs of biogas power generation for various types of biogas projects. Obviously, the most dynamic unit output costs (The discount rate is 8%) of biogas power generation is more than 0.5 Yuan/KWh, and much more higher than the coal power generation. Due to high initial investment and cost, low internal rate of return and lacking in profitability capacity, the biogas themselves can not compete with conventional energy in gas-fired and generation market.

Table 5 Unit Output Cost of Biogas Power Generation for Various Types of Biogas Projects

Biogas project type		Unit production cost of biogas (Yuan/ m^3)		Unit production cost of power generation (Yuan/ kWh)	
		0%[1]	8%[2]	0%[1]	8%[2]
Agriculture	Energy - environmental protection type	0.68	1.05	0.46	0.73
	Energy - ecological type	0.55	0.87	0.4	0.62
	Comprehensive utilization type	0.37	0.55	0.27	0.43
Industry	Qingdao Distillery	0.23	0.32	0.22	0.30
	Fengbao Distillery	0.39	0.52	0.41	0.53

Note [1]: The discount rate is zero, i.e. static state.

[2]: The discount rate is 8%.

Besides the shortages of themselves, another important reason of biogas projects lacking in market competitiveness is that the technical system of the biogas project can not adapt to the requirement for industrial scale development. The main problems are biogas technology needing further advance; no unified national standard for the design and construction of the biogas project and lack of authentication standard for construction qualification; some key equipment not in the specialized production and no standardized and complete set of products; control and monitoring for biogas project in our country still operated and managed by hand which brings about an impact on the normal operation; low level of management and so on.

3.2 The nationwide biogas market has not been set up.

The biogas project has the characteristics of small scale and decentralized management, and the limited gas and power can be provided each day. If they are provided to the consumer by public institutions and enterprises such as gas company or power grid enterprise, it will bring about a lot of management problems for the energy enterprise, such as operation, safety, load match and so on. Furthermore, the gas company and power grid enterprise have to purchase them at a price which is higher than conventional price and this can hardly be accepted by them without policy support.

Now the biogas technology is under its way of development and improvement. As a product, the biogas and its power is lack in a set of authentication systems including rigid product standard and monitoring, and market access system. Currently, the biogas and its power can not become the formal products in the market and this seriously hinders the foundation and development of biogas market.

3.3 The biogas projects is lack in national supporting policy.

Although our governments at all levels have put forward and implemented many incentive policies on environmental treatment and clean energy development, there are still lack of a complete policy system for development of renewable energy including biogas because of that all the current policies are partial and only support actual projects. There is not a definitely encourage mechanism for investment, subsidy, the price of fired gas and electricity, tax-free and credit.

4. Measures for Overcoming Barriers and Policy Support.

4.1 Establish the concept that the biogas project is the integrated basic industry.

The first thing to do is to change the concept that regards the biogas project only as a kind of energy project. The biogas project not only treats the sewage discharged from many sectors such as light industry, livestock farm etc., improves environment condition, but also provides clean fuel and power. At the same time, it turns the sewage into high-effective organic fertilizer, so as to make a full use of the resource. It covers many areas of energy, environment and resource. Therefore it can be regarded as an integrated basic industry of making full use of the resources and realizing recycling economy.

4.2 Realizing industrial development of biogas project with policy support.

Although the development of one industry must obey the market development rule, the biogas project must depend on the policy support in beginning of establishment and development because of many shortage of itself. So, the correct ideology of industrial scale biogas development is needed.

(1) Objective orientation: Based on the national law, regarding the quantitative target on the development of biogas as market demand to promoting market development.

(2) Enterprise is the main body in the market. Instead of the government, the enterprises are the main undertakers for environmental treatment and production of biogas and its power. Only with the participation of more enterprises, can the products of biogas project enter into the market, develop in scale and grow into industry.

(3) The duty of the government: defining development objective; providing preferential policy support, including price, financial subsidy tax-free, credit and so on; fostering market; establishing market access system; enhancing capacity building of technology, production criterion, authentification, service and monitoring system.

4.3 Measures and policies.

China Renewable Energy Law will be implemented from Jan 1, 2006 and the central and region government at all levels are establishing 11^{th} Five-Year-Plan (2006-2010), 2020 Programming, and the implement detailed rules of China Renewable Energy Law. So, we believe that biogas project will make a great progress. At the aspect of detailed measure and policy, we advise as follows.

(1) Objective definition and market orientation.

• Combining with the objective of industrial and agricultural organic wastewater, affirming the location of biogas development in the energy system of our country. Working out legal based quantitative target of the biogas and its power development to guide the market with the demand.
• Strengthening the law implementation of environmental objective, promoting the enterprises to complete the treatment task.

(2) Improving the market competitiveness of the enterprises themselves.

• Selecting the right technology and technical mode, expanding scale and reduce cost.
• Developing specialized biogas management enterprises, with independent management, centralized treatment and reduced cost.

(3) Forming and standardizing the biogas market.

• Establishing and perfecting the criterion, authentication, supervision and service system of the technology and product.
• Setting up the market access system of biogas and its power, the power grid company must purchase biogas power.

(4) Policy support for the enterprises to gain profits.

・Implementing preferential sheltered price (prices of electricity and gas).
・Setting up special financial fund.

(5) Implementing policy financing.

・Listing the biogas projects into the basic area supported by the policy financing of the State Development Bank of China and the Agriculture Development Bank of China, implementing policy financing.
・Gradually developed into finance system for specialized industrial scale development of basic facilities.

(6) Public participation.

・ Enhancing the public awareness of environmental protection and clean energy, encouraging the public to take an active part and support the industrial scale development of biogas.

The each one of above 6 aspects has its own pertinence, indicating the requirements for the enterprise, market and government in the industrial scale development of the biogas project. From comparison, the most pivotal points, which especially put forward in the study report, are four of them, these are developing specialized biogas management enterprises, the power grid company should purchase biogas power, implementing fixed price and policy financing.

Reference:

Abbreviation and Unit Symbols.

Abbreviation		Unit symbols	
AF	Aerobic Filter	D	Day
COD	Chemical Oxygen Demand	kW	Kilowatt
CSTR	Completely Stirred Tank Reactor	kWh	kilowatt-hour
EGSB	Extensive Granular Sludge Bed	m^3	cubic meter
IC	Internal Circulation Reactor	MJ	Megajoule
IRR	Internal Rate of Return	t	ton
UASB	Up-flow Anaerobic Sludge Blanket	tce	tons of coal equivalent
UBF	Up-flow Sludge Bed Filter		

China Renewable Energy Roadmap:

The International Context and Other Roadmap Experience

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1. China Renewable Energy in International Context

Currently, China leads the world in installed renewable power capacity, with 37 GW out of 160 GW worldwide (Table 1). Germany and the United States follow China, then Spain and Japan. However, most of China's capacity is small hydro, and there is large potential for China to catch up to other countries in wind and biomass power generation. The growth of grid-connected solar photovoltaic is accelerating in some developed countries, particularly Germany, Japan, and the United States, but has not started yet in China.

Wind Power. Wind power capacity went from 570 MW in 2003 to 770 MW in 2004, compared with global wind installations of 8,100 MW in 2004 and a global total of 48,000 MW existing. There is one primary domestic manufacturer, Goldwind, which had a market share of 20%. Gamesa and NEG-Micon were the top two foreign manufacturers with market shares of 36% and 29%, respectively. GE Wind entered the Chinese market for the first time, and it had a market share of 8%.

Biomass Power. Biomass power generation capacity is small in China, about 2,300 MW, compared to the global total of 39,000 MW, partly because of the high costs and difficulties of transporting biomass feedstocks to central locations, and the need for better combustion technology.

Hydro Power. In 2004 there was 105 GW total hydro power generating 330 TWh, including about 34 GW of small hydro generating 98 TWh. Hydro represented almost 25% of China's total power capacity of 450 GW in 2004. Small hydro has grown from 25 GW in 2000 and 16 GW in 1995, and now represents more than half of the global total of 61 GW small hydro.

Solar PV. As of 2004, China had 100 MW of PV module production capacity, compared to world total production capacity of 1200 MW. Chinese production capacity doubled during 2004. Cell production capacity was 65 MW in 2004, and wafer production capacity was 15 MW. These are expected to increase to 200 MW each in 2005. Total existing installations of solar PV were 65 MW as of end-2004, about 50% of this in rural (off-grid) areas. Communications and industry account for most of the other 50%, with consumer products a small share also. Grid-connected PV is still marginal, less than a megawatt, compared to 700 MW added in Germany, Japan, and .the United States in 2004 alone, and existing global total of 1,800 MW.

Solar hot water. Almost 60% of the world's installed solar hot water capacity exists in China (Table 2). China accounted for 80% of installations worldwide in 2004, and this trend is expected to continue. Unlike international markets, where flat-plate collectors are most common, the glass vacuum tube was the most common type in the Chinese market, with a market share of 88% in 2003. There are more than 1000 manufacturers throughout the country, with an estimated 250,000 people employed in the industry. This employment represents almost 15% of total employment in all renewable energy industries worldwide. The cost of Chinese solar hot water heaters is an order of magnitude cheaper than European counterparts. In 2002, 70% of all solar hot water heaters were sold at prices below RMB 1600 ($200), which given typical sizes of 2 m2, comes to $100/m2. This compares with typical European costs of $800-1000/m2.

Biofuels. Chinese production of biofuels is just starting, with China accounting for perhaps 5% of global ethanol production in 2004 (Table 3). As of late 2004, there were four provinces, Heilongjiang, Jilin, Liaoning, and Henan, which required ethanol to be mixed with gasoline in a 10% ratio (E10). The government planned to extend these requirements to five other provinces, Hebei, Anhui, Hubei, Shandong and Jiangsu, by late 2005 (although perhaps would not required in the entire province). China's seven provinces with mandates compare to about six other provinces/states worldwide with such mandates.

Rural (off-grid). There are an estimated 7 million un-electrified households remaining in rural areas of China, representing about 28 million people. There are now an estimated 450,000 to 500,000 solar home systems installed in rural areas, representing about 25% of the global total of rural solar home systems. More than 230,000 solar home systems have been sold since 2002 under the World Bank/GEF Renewable Energy Development Project, about one-half of total World Bank-supported installations worldwide. China has had major projects for rural electrification in recent years, including the Township Electrification program, which electrified one million people in less than two years; this is the largest single rural electrification program using renewables in the world. About 12 million households have household-scale biogas digesters, compared to the global total of 16 million households. Some estimate that more than 1 million biogas digesters are being produced each year, aided by a government subsidy program started in 2002.

Table 1. New Renewable Electric Power Capacity, GW existing as of 2004

Technology	World Total	Developing Countries	EU-25	China	Germany	U.S.	Spain	Japan
Small hydropower	61	39	13	34	1.6	3.0	1.6	3.5
Wind power	48	4.3	34.2	0.8	16.6	6.7	8.3	0.9
Biomass power	39	22	8	2.3	0.9	7.2	0.3	> 0.1
Geothermal power	8.9	4.5	0.8	< 0.1	0	2.5	0	0.5
Solar photovoltaic-grid	1.8	0	0.9	0	0.7	0.1	0	0.8
Solar thermal electric	0.4	0	0	0	0	0.4	0	0
Ocean (tidal) power	0.3	0	0.3	0	0	0	0	0
Total renewable power capacity (excluding large hydro)	160	70	57	37	20	20	10	6
For comparison:								
Large hydropower	740	330	90	70	n/a	90	n/a	45
Total power capacity	3,800	1,400	580	440	n/a	860	n/a	260

Source: REN21 “Renewables 2005 Global Status Report.”

Table 2: Solar Hot Water Installed Capacity, Top 10 Countries/EU and World Total, 2004

Country/EU	Existing 2003 (million m^2)	Additions 2004 (million m^2)	Existing 2004 (million m^2)
China	50.8	13.5	64.3
EU	13.1	1.6	14.0
Turkey	9.5	0.8	9.8
Japan	7.9	0.3	7.7
Israel	4.7	0.4	4.9
Brazil	2.2	0.2	2.4
United States	2.1	0.05	2.0
Australia	1.4	0.1	1.5
India	0.9	0.1	1.0
South Africa	0.5	--	0.5
(other countries)	< 2	--	< 2
World Total	95	17	110

Source: REN21 “Renewables 2005 Global Status Report.”

Table 3. Biofuels Production, Top 10 Countries, 2004 (billion liters)

Country	Ethanol (billion liters)	Biodiesel (billion liters)
Brazil	15	---
United States	13	0.1
China	2	---
Germany	0.02	1.1
France	0.1	0.4
Italy	---	0.35
Canada	0.2	---
Thailand	0.2	---
Spain	0.2	---
Denmark	---	0.08
World Total	31	2.2

Source: REN21 "Renewables 2005 Global Status Report."

2. China's National Targets in International Context

Policy targets for renewable energy exist in at least 45 countries worldwide. By mid-2005, at least 43 countries had a national target for renewable energy supply, including all 25 EU countries (Table 4). In addition to these 43 countries, 18 U.S. states (and DC) and 3 Canadian provinces have targets based on renewables portfolio standards (although neither the United States nor Canada has a national target). An additional 7 Canadian provinces have planning targets. Most national targets are for shares of electricity production, typically 5–30 percent. Electricity shares range from 1 percent to 78 percent. Other targets are for shares of total primary energy supply, specific installed capacity figures, or total amounts of energy production from renewables, including heat. Most targets aim for the 2010–2012 timeframe.

The 43 countries with national targets include 10 developing countries: Brazil, China, the Dominican Republic, Egypt, India, Malaysia, Mali, the Philippines, South Africa, and Thailand. A few other developing countries are likely to announce targets in the near future. Thailand is targeting 8 percent of primary energy by 2011 (excluding traditional biomass). India is expecting 10 percent of added electric power capacity, or at least 10 GW of renewables, by 2012. The Philippines is targeting nearly 5 GW total by 2013, or a doubling of existing capacity. South Africa in 2003 set a target of 10 TWh of additional final energy from renewables by 2013, which would represent about 4 percent of power capacity. The Mexican legislature was considering in 2005 a new law on renewable energy that would include a national target.

China has ambitious development targets for 2010 and 2020 (Table 5). China's target of 10% of total power capacity by 2010 (excluding large hydropower) implies 60 GW of renewables capacity given projected electric-power growth (expected 600 GW capacity by 2010). China also has targets for 2020, including 10% of primary energy and 20% of power capacity, 300 million square meters of solar hot water, 30 GW of wind power, and 20 GW of biomass power. A 20% capacity target by 2020 would represent about 190 GW out of a predicted 950 GW power sector capacity in 2020 (prediction by China Electric Power Research Institute).

Table 4: National/EU Renewable Energy Targets

Country	**Target(s)**
Australia	9.5 TWh of electricity annually by 2010.
Brazil	3.3 GW added by 2006 from wind, biomass, small hydro.
Canada	3.5% to 15% of electricity in 4 provinces; other types of targets in 6 provinces.
China	10% of electric power capacity by 2010 (expected 60 GW); 5% of primary energy by 2010; 20% of power capacity and 10% of primary energy by 2020.
Dominican Rep.	500 MW wind power capacity by 2015.
European Union	21% of electricity and 12% of primary energy by 2010. Individual country targets for electricity by 2010 range from 3.6% in Hungary to 78% in Austria.
Egypt	3% of electricity by 2010 and 14% by 2020.
India	10% of added electric power capacity during 2003–2012 (expected 10 GW).
Israel	2% of electricity by 2007; 5% of electricity by 2016.
Japan	1.35% of electricity by 2010, excluding geothermal and large hydro (RPS).
Korea	7% of electricity by 2010, including large hydro, and 1.3 GW of grid-connected solar PV by 2011, including 100,000 homes (0.3 GW).
Malaysia	5% of electricity by 2005.
Mali	15% of energy by 2020.
New Zealand	30 PJ of added capacity (including heat and transport fuels) by 2012.
Norway	7 TWh from heat and wind by 2010.
Philippines	4.7 GW total existing capacity by 2013.
Singapore	50,000 m^2 (~35 MWth) of solar thermal systems by 2012.
South Africa	10 TWh added final energy by 2013.
Switzerland	3.5 TWh from electricity and heat by 2010.
Thailand	8% of total primary energy by 2011 (excluding traditional rural biomass).
United States	5% to 30% of electricity in 20 states (including DC).

Source: REN21 “Renewables 2005 Global Status Report.”

Table 5: China Development Targets (still under governmental review)

	Year 2010	**Year 2020**
Hydro power	160 GW	300 GW
Wind power	5 GW	30 GW
Biomass power	5 GW	20 GW
Solar hot water	---	300 million m2
Solar PV	---	1 GW
Biomass use	1 million tons	50 million tons
Biogas and biomass gasification	11 billion m3/year	22 billion m3/year
Share of total primary energy	5%	10%
Share of electric power capacity	10%	20%

Source: NDRC, Energy Bureau, September 26, 2005

3. International Approaches to Renewable Energy Futures

There are at least six basic approaches to thinking about renewable energy futures in the literature:

- National/regional targets. Establish a national goal, development plan, or legally mandated target for a certain amount of renewable energy by a fixed date, either in terms of percentage, absolute capacity, or incremental additions. Over 48 countries around the world now have national and/or regional targets established for renewable energy.

- General energy scenarios. Assume growth trends from the present for each energy source, including total growth in energy demand. May account for changes in technology and costs. Examples are the International Energy Agency's "World Energy Outlook" and "Energy to 2050: Scenarios for a Sustainable Future."

- Renewable energy future shares. Assume or assert a certain future share of electricity or energy from renewables. Argue the practicality (including the implied annual growth rates) and discuss implications in terms of costs, required investments, employment, and environmental benefits. An example is the blueprint "Wind Force 12" by the European Wind Energy Association and Greenpeace.

- Greenhouse-gas emissions reductions. Assume or assert a future CO_2 reduction level, relative to 1990 baseline level, and then consider alternative scenarios to achieve that level of CO_2 reductions. Argue the practicality and discuss implications in terms of costs, required investments, employment, and environmental benefits. An example is the ECN Policy Studies paper "Two Visions for the Dutch Energy System in 2050."

- Detailed industry development roadmaps. Chart the development of a national industry in terms of technological progress, business investment, and markets. Consider different policy and market instruments and how these could affect industry progress. An example is the U.S. National Renewable Energy Laboratory (NREL) “Solar Electric Power: The U.S. Photovoltaic Industry Roadmap.”

- Learning/experience curve literature is also used to determine future costs, such as in “Wind Force 12.” This allows estimation of future economic competitiveness and assessment of the viability of different levels of investment and penetration.

- Detailed plans/visions at the city scale. Urban planning processes and overall visions, such as the share of houses with “solar rooftops” by a certain, underlie concrete urban plans for renewable energy, often with CO2 reduction goals as well. An example is the city of Goteborg, Sweden, and its “Goteborg 2050” urban development plan.

Examples of each of these approaches are presented below.

4. Developing a Scenario – Key Elements (IEA)

According to IEA experience, a fundamental requirement of scenarios is that they be internally consistent, logical and plausible constructs of how the future might unfold. Furthermore, scenario building is an inherently interdisciplinary process, because it needs to take into account the many dimensions of the same problem. Scenarios need to integrate long-term phenomena (including demographic, technological or ecosystem trends) with shorter-term phenomena (like inflation or spikes in oil prices). The process of scenario building is a complex analytical exercise. Five main steps are discernible:

- Define the problem and its horizon or isolate the decision that needs to be made.
- Gather information, expert opinion and past data on the system under investigation and build a coherent system that includes all relevant actors and agents, including the factors and links (both quantitative and qualitative) between them.
- Identify the key factors that would affect decisions and separate predetermined or unavoidable factors and trends from those that are highly uncertain or depend on will.
- Rank these factors by importance for the success of the focal issue (defined in step 1) or by uncertainty and identify the two or three factors or trends that are most important and most uncertain. These will represent the main axes along which scenarios will differ and will be characterised. Predetermined elements/factors will remain unchanged in all scenarios.
- Flesh out the scenarios in the form of consistent narratives or "stories". The next logical step is to examine the implications of the various scenarios and translate

them into clear strategic choices. Different choices can at that point be tested for robustness/resilience against the scenarios outlined.

This process corresponds to so-called "**exploratory**" or "**descriptive**" scenarios, built for the purpose of exploring a range of outcomes and analyzing their implications for strategic decision-making. The main value added in exploratory scenarios lies in the fact that they help prepare for turns of those events that are plausible and entirely possible without representing a straight-line continuation of past and present trends.

Scenarios, however, can also be "**normative**" or "**strategic**". In this case the perspective is changed: a "desirable" vision of the future, or a goal in the future, is outlined. What is considered "desirable" clearly depends on the general objectives of the individual or group elaborating the scenario. An example could be a sustainable scenario characterised by stabilisation of GHG concentrations at 450 ppm by the end of this century. These objectives are used as a point of departure from which to travel backward and identify the conditions that must be fulfilled or measures to be taken at different stages along the path in order to implement that vision or achieve that goal.

Typically, normative scenarios tend to work in a "back-casting mode". This represents a critical change of perspective. It provides a useful mechanism to focus attention on several crucial elements: actions that must be taken and conditions that must be created at certain points in time in order to make the scenario achievable. The emphasis is on planning to achieve a certain result rather than on preparedness in responding to uncertain events. The attitude is more proactive, and policy intervention is a tool of choice. Building a normative scenario requires rationalization at the initial stage in order to define desirable characteristics of the future state of affairs, and to express them as measurable targets. Furthermore, the exercise stimulates formulation of critical questions, the recognition of uncertainties, the identification of bottlenecks and priority areas for policy action as well as for research and technological development.

While "exploratory" scenarios set the groundwork to describe what could happen, "normative" scenarios help decide what one could or should do, and hence are more concerned with action. In practice, normative scenarios of this type are rarely found in isolation, i.e. without previous analysis of what the future might bring.

Another common distinction is between "qualitative" and "quantitative" scenarios. The former are pure narrative stories describing how the future might unfold or the relationships internal to the system analyzed, without the help of figures. The latter also give a numerical illustration of the evolution of key variables or indicators. Quantitative scenarios are often represented through the use of a model, but may be also illustrated through much simpler tools.

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5. International Energy Agency "Energy to 2050: Scenarios for a Sustainable Future"

This study developed three descriptive global scenarios and one normative scenario:

- "Clean but not sparkling": describes a world of slow technological change, high concern for the global environment;
- "Dynamic and careless": describes a world of fast technological change, low concern for the global environment;
- "Bright skies": describes a future of fast technological change, high concern for the global environment.
- "Sustainable Development (SD) Vision": calls for a 60% share of "zero carbon" sources in total world primary energy supply, by the year 2050.

The common assumption across the three descriptive scenarios is that there are sufficient fossil energy resources to meet demand in the next 50 years; whether they will actually be extracted depends on the pace and direction of technological change and on the level of environmental concern. The matching of supply and demand will continue to take place at the global level, subject to the preconditions of uninterrupted supply, economic affordability and ecological suitability. However, the relative weight of these three elements will vary depending on the world envisaged.

Total primary energy demand will increase in aggregate terms in all scenarios. The link between growth in income and growth in energy demand will continue but its character changes depending on the scenario. Thanks to improving technology, newly industrialising countries will be in a position to use less energy than did the industrial countries at similar income levels in the past. Whether this potential for lower energy intensity is fully tapped will depend on other scenario characteristics. Continuation of trends to improve energy intensity at least at the aggregate level is likely. At global level energy efficiency improvements will slow demand growth but not offset it. The general trend will be towards convergence in energy end-use patterns and services between developed and developing countries although the convergence in energy consumption levels is not necessarily assumed.

The role of renewables in these descriptive scenarios is as follows:

Scenario 1: Clean but Not Sparkling.

In developed countries, solar PV technology will improve its conversion efficiency but very slowly. Wind power, already competitive, will take a considerable share of the electricity market, exploiting as much as possible all good sites, provided that conflicts with other land uses do not arise. Commercial biomass use for energy production will also expand, favoured by improvements in biotechnologies. Bio-fuels, free from the problems of intermittence that characterise other renewables, will be increasingly used for power generation.
In developing countries, renewables like solar PV, wind and biomass, do not see

dramatic technological improvements or cost reductions from accelerated adoption measures in developed countries. But due to environmental preferences of developed countries and favourable financing terms offered by them, renewables are pushed through the market and start to expand rather fast in developing countries too, where the renewable resource potential is much larger. More conventional renewables, such as hydro, will be also exploited to close to their maximum potential, even amid increasing opposition by displaced populations and environmentalists. Solar PV technology only slowly will improve its conversion efficiency, and thus costs will decrease equally slowly. However, wind power, already competitive, will take a considerable share of the electric market wherever wind conditions are good and conflicts with other land uses do not arise. Commercial biomass use for energy production will also expand, favoured by improvements in agricultural practices and in biotechnologies. Bio fuels, free from the intermittence problems that characterise other renewables, will be increasingly used for power generation, but their use will also be expanded as fuel additives to power vehicles.

Scenario 2: Dynamic But Careless

With continuing high costs, the attention towards certain renewable technologies like solar PV will remain modest, but investment in the cheapest renewable options (wind, biomass and hydro, where possible) will increase. By 2035-2050, wind technologies would have survived in the best sites and in some market niches, but solar PV would not have improved much. High temperature solar thermal applications for electricity generation would have slowly developed to reach fairly high conversion efficiencies and attractive economics. They would be ready for larger scale adoption.

Scenario 3: Bright Skies

Over the first 20 years of the scenario, renewable energy use would have grown, and prices dropped, making them increasingly competitive, partly thanks to policies that favour them in terms of fiscal advantages. Wind technologies would have become cheaper thanks to economies of scale, manufacturing volume, better materials and R&D advancement. Solar PV technologies would also have become cheaper thanks to improvement in thin-films technology, improved conversion efficiencies, and better integration in building architecture. Improvements in technologies for power-grid management would also have contributed to their increased success. High temperature solar-thermal applications for electricity generation would have evolved to reach fairly high conversion efficiencies and competitive economics. They would be ready for larger scale adoption. Power storage technologies would also have improved. On the other hand, technologies for biomass energy production (direct heat, electricity or liquid and gaseous fuels) would also have improved, and become competitive. However more aggressive deployment tactics and continued R&D will stimulate production of power on a scale comparable to that of conventional thermal plants.

Normative Scenario: The "Sustainable Development (SD) Vision

This scenario calls for calls for a 60% share of "zero carbon" sources in total world primary energy supply, by the year 2050. Renewables make up about 35% of global primary energy, about half of that from biomass. Biomass grows by 2.5-3% per year, and other renewables grow by 4.5-6% per year through 2050. Increasing the share of biomass production in TPES from almost 11% in 2000 to 15.7% in 2050, as envisaged by the SD Vision scenario requires a more than three-fold increase in production. To achieve a share like the one envisaged in the SD Vision scenario, the rate of growth of global biomass supply over the coming 50 years must be almost twice as high as the one experienced in the past 10 years. For the other renewable energy sources (hydro, wind, solar PV, solar thermal, solar concentrating technologies, geothermal, etc.) increasing the share from 3.6% in 2000 to 18.9% in 2050 requires a thirteen-fold increase in energy output. This means sustaining, over the coming 50 years, growth rates between 4.5 and 6% per annum, which could be attained based on historical rates of 3.4% in the years 1990-2000.

For renewables to achieve the market penetration rates indicated by the SD Vision scenario would require aggressive policy intervention. Deployment and market development policies should be implemented as soon as possible to prepare for the acceleration that should take place, especially for non-biomass renewables, after 2020.

6. Global Wind Energy Council and Greenpeace "Wind Force 12"

Wind Force 12 is a global industry blueprint which demonstrates that there are no technical, economic or resource barriers to supplying 12% of the world's electricity needs with wind power alone by 2020 - and this against the challenging backdrop of a projected two thirds increase of electricity demand by that date. By 2020, 1,250 GW of wind power can be installed.

The main inputs to this study have been: (a) an assessment of the world's wind resources and their geographical distribution. (b) the level of electricity output required and whether this can be accommodated in the grid system. (c) The current status of the wind energy market and its potential growth rate. (d) Analysis of wind energy technology and its cost profile. (e)A comparison with other emerging technologies using "learning curve theory".

The study assumes, that on the basis of recent trends, it is feasible that wind power can be expected to grow at an average rate for new annual installations of 25% per annum over the next seven years. This is the highest growth rate during the timescale of the study, ending up with a total of 197,500 MW of capacity on line by the end of 2010. From 2011 to 2014, the growth rate falls to 20% per annum, resulting in 453,800 MW of installed capacity by the end of 2014. After that the annual growth rate falls to 15%, and then to 10% in 2019, although by this time the expansion of wind power will be taking place at a much higher level of annual installation. By the end of 2020, the scenario shows that wind power will have achieved a global installed capacity of over 1.2 million MW. This represents an output of 3,000 TWh, a penetration level equivalent to 12% of the world's electricity demand.

The main assumptions are:

(1) Annual growth rates: Growth rates of 20-25% are high for an industry manufacturing heavy equipment, but the wind industry has experienced far higher rates during its initial phase of industrialisation. Over the last five years the average annual growth rate of cumulative turbines installed has been almost 32%. After 2015, the scenario growth rate falls to 15% and then to 10% in 2019. In Europe, an important factor will be the opening up of the offshore wind market. As far as developing countries are concerned, a clear message from the industry is that it would like to see a stable political framework established in emerging markets if this expansion is to be achieved.

(2) Progress ratios: Industrial learning curve theory suggests that costs decrease by some 20% each time the number of units produced doubles. The progress ratios assumed in this study start at 0.85 up until 2010. After that the ratio is reduced to 0.90 and then to 1.0 in 2026.

(3) Growth of wind turbine size: The average size of new turbines being installed is expected to grow over the next decade from today's figure of 1,200 kW (1.2 MW) to 1.5 MW in 2007 and 2.0 MW in 2013. Larger turbine sizes reduce the number of machines required.

(4) Comparisons with other technologies: Both nuclear power and large scale hydro are energy technologies which have achieved substantial levels of penetration in a relatively short timescale. Nuclear has now reached a level of 17.1% globally and large hydro 16.6%. Wind energy is today a commercial industry which is capable of becoming a mainstream power producer. The time horizon of the 12% scenario is therefore consistent with the historical development of these two technologies.

The annual investment required to achieve the deployment of wind energy outlined above starts at e 8.2 billion in 2004 and increases to a peak of e 82.7 billion by 2019. The total investment needed to reach a level of almost 1,200 GW of capacity by 2020 is estimated at e 692 billion over the whole period. This is a very large figure, but it can be compared with the annual investment in the power sector during the 1990s of some e 158-186 billion. The future investment required globally has also been broken down on a regional basis.

Using the progress assumptions already discussed, and taking into account improvements both in the average size of turbines and in their capacity factor, the cost per kilowatt hour of installed wind capacity is expected to have fallen to 3.03 e cents/kWh by 2010, assuming a cost per installed kilowatt of e 644. By 2020 it is expected to have reduced to 2.45 e cents/kWh, with an installation cost of e 512/kW - a substantial reduction of 36% compared with 2003.

The employment effect of the 12% wind energy scenario is that a total of 2.3 million jobs will have been created around the world by 2020 in manufacture, installation and other work associated with the industry.

On the assumption that the average value for carbon dioxide saved by switching to wind power is 600 tonnes per GWh, the annual saving under this scenario will be 1,832 million tonnes of CO2 by 2020 and 5,106 million tonnes by 2040. The cumulative savings would be 10,771 million tonnes of CO2 by 2020 and 88,857 million tonnes by 2040.

The overall results are as follows:

WIND FORCE 12: SUMMARY RESULTS IN 2020

Total MW installed	1,254,030
Annual MW installed	158,728
TWh generated to meet 12% global demand	3,054
Co2 reduction (annual million tonnes)	1,832
Co2 reduction (cumulative million tonnes)	10,771
Total investment per annum	€80 billion
Total job years	2.3 million
Installation costs in 2020	€512/kW
Electricity generation costs in 2020	€2.45cents/kWh

7. U.S. National Renewable Energy Laboratory (NREL) Solar Industry Roadmap

The U.S. National Renewable Energy Laboratory (NREL) “Solar Electric Power: The U.S. Photovoltaic Industry Roadmap” details activities by industry and government over the near-term (1-3 yrs), mid-term (4-10 yrs), and long-term (11-20 yrs) to build markets, as shown in the following table.

The goal of the roadmap is to achieve 7 GW of annual production by 2020 in the U.S. PV industry, up from 100 MW in 2002. This represents an annual average growth rate of 25%. It also represents a cumulative share of U.S. shipments of almost 50%

relative to the rest of the world. (Note: this cumulative share seems highly unrealistic in light of recent developments since the roadmap was first written in 2001. The U.S. share of global PV production was only 13% in 2004, and annual production had increased to only 140 MW.)

The "endpoint" in 2020 is that the domestic photovoltaic industry will provide up to 15% (about 3.2 GW annually) of new U.S. peak electricity generating capacity expected to be required in 2020. Cumulative U.S. PV shipments will be about 36 GW at this time.

By 2010, the system price paid by the end-user (including operating and maintenance costs) will be $3 to $4 per watt AC. Cost reduction will continue through 2020.

Near-Term (1-3 Years)	**Mid-Term (4-10 Years)**	**Long-Term (11-20 Years)**
RESEARCH AND DEVELOPMENT – INDUSTRY ROLE		
• Develop advanced PV production equipment • Improve throughput of products in manufacturing processes • Enhance investment capital • Integrate R&D activities • Create manufacturing partnerships • Garner industry consensus and framework for Manufacturing Center of Excellence, and initiate operations • Develop prepackaged PV systems for reduced cost and improved reliability	• Develop model for high-volume manufacturing • Ensure steady flow of available silicon • Agree on common equipment standards • Research thin-film packaging • Develop technology (e.g., building-integrated PV, architectural glass) • Develop small-scale, standardized PV products for easy installation suitable for do-it-yourselfer market • Standardize PV systems for utility installation on utility grids • Complete fully operational Manufacturing Center of Excellence	• Create new materials and devices with high efficiency and low cost • Develop quality assurance/quality control methods to test products on site • Expand operation of Manufacturing Center of Excellence in response to technology directions
RESEARCH AND DEVELOPMENT – GOVERNMENT ROLE		
• Increase R&D emphasis on manufacturing improvements • Expand the use of PV in	• Sponsor R&D to improve lifetime of PV modules and systems • Continue PV R&D	• Support basic research on materials for the next generations of solar-electric PV systems

government facilities where it makes economical/technical sense • Continue PV R&D activities • Support Manufacturing Center of Excellence	activities • Continue support for Manufacturing Center of Excellence	• Continue support for Manufacturing Center of Excellence
MARKET OPPORTUNITIES – INDUSTRY ROLE		
• Increase sales and marketing budgets • Invest in manufacturing capabilities to meet demand in USA and abroad • Support an independent, proactive industry association	• Obtain long-term, low interest financing for PV • Build manufacturing capabilities • Develop business models, rules, and products for utility and power generator use of PV as peak shaving alternative	• Foster robust domestic and international market for PV
MARKET OPPORTUNITIES – GOVERNMENT ROLE		
• Establish moderate residential tax credits (state and federal) • Create manufacturing incentives (equity with other energy-product producers) • Invest in PV for facilities owned and operated by government • Support retail competition, as well as customer options under traditional regulation, as opportunities for customer acquisition of PV	• Invest in retail infrastructure distribution network • Continue outreach, training, and public awareness projects	• Fully develop outreach, training, and public awareness training • Lobby for utility regulatory policies and practices that provide open and competitive market for PV
POLICY AND INSTITUTIONAL ISSUES – INDUSTRY ROLE		
• Increase understanding and public awareness for business executives, federal and state policy makers, and consumers about solar electricity • Lobby for fair and equitable utility practices that allow solar electricity	• Invest in retail infrastructure distribution network • Continue outreach, training, and public awareness projects	• Fully develop outreach, training, and public awareness training • Lobby for utility regulatory policies and practices that provide open and competitive market for PV

to compete on a level playing field • Support retail competition, as well as customer options under traditional regulation, as opportunities for customer acquisition of PV		
POLICY AND INSTITUTIONAL ISSUES – GOVERNMENT ROLE		
• Adopt net metering in all 50 states • Adopt uniform interconnection standards in all 50 states • Establish fair and equitable utility business practices for PV, e.g., standby charges, customer retention fees • Support broad outreach aimed at business executives, state and federal policy makers, and consumers regarding solar electricity • Give credit for PV in "urban airshed" programs for offsetting emissions	• Support national and international standards for PV products and components (e.g., ratings, verification tools) • Support PV infrastructure development (codes, standards, certification) • Establish environmental regulations that explicitly value clean energy solutions such as PV	• Continue to develop regulatory and policy framework that supports PV • Support tax incentive structure that encourages development of clean energy

8. Netherlands ECN Policy Studies: Two Visions of the Dutch Energy System in 2050

Two long-term visions of the Dutch future energy system are composed, analyzed and evaluated. Both visions were set up to meet the requirement to reduce the GHG emissions with 80% in 2050 in comparison to 1990. This study took a four-part methodology and came up with two visions “A” and “B”:

1. Establish the social, demographic and economic context.
2. Chose specific economic growth scenarios
3. Inventory the technological options for GHG reductions, related to the socio-economic contexts, in terms of availability of the technology within a vision, societal preference for and acceptance of certain technologies, and internal coherence between the options in one vision.
4. Conduct a quantitative analysis of the energy balance and GHG emission levels for

the different visions.

Table 1: Main characteristics of the assumed socio-economic contexts that are used as the basis for the two visions and subsequent energy systems

	Vision A	Vision B
World view	Internationally oriented, "Global Village"	Regionally oriented, world trade blocks
	World-wide convergence	
Social	Individualistic	Sociable, family oriented
environment	Environment and nature:economic value	Environmentally minded
	Own interest first	Distribution of wealth, social equity
Economy and	High economic growth and dynamics	Less dynamics and economic growth
consumption	The market rules, little government regulations	Regulation, strong government
	Recreation abroad	More nature areas/domestic recreation
	Quantity above sustainability	Durable goods, quality
Traffic	High demand for passenger mobility &freight	High demand for passenger mobility
and transport		moderate demand freight transport
	Private transportation dominates	Public transportation relatively popular
	Freight transport by road	More freight trains and inland shipping
Energy and	Quick development and diffusion of technology	Technology develops less quickly
environment	New infrastructure quick to implement	Solutions on demand side important
	No change in behaviour	Willingness to adapt behaviour
	Cost–benefit analysis	Priority to environment and sustainability

Each sector of the economy is modeled under Visions A and B to come up with total energy demand and characteristics. Then energy supply combinations are constructed.

In Vision A, renewables such as wind and PV only play a moderate role, mainly because of high costs. Off-shore wind energy contributes for 10% to the electricity supply, while the application of PV is limited to niche markets.

In Vision B, there is an impressive development of wind-power capacity, both on-shore and off-shore. The potential of wind-power generation is about 15,000MWe installed capacity. This results in a net contribution to the power generation of about 40%. Photo-voltaic energy is assumed to be fully integrated in the build environment. The bulk of the remaining energy needs is supplied by bio-energy. 'Bio-energy refineries' where bio-alcohols are produced as well as hydrocarbons, are the main consumers of biomass. A small part of the biomass originates from indigenous sources, but the bulk of biomass, however, is imported. The Netherlands needs about 4 million hectares abroad to produce biomass and biofuels needed to meet the projected share in national energy demand.

Primary energy demand in Vision A is 2000 PJ, while in Vision B it is 1850 PJ. In

Vision A, renewables supply 46% of primary energy, mostly biomass with some solar thermal. In Vision B, renewables supply 81% of primary energy, still mostly biomass but also including significant shares of wind, solar thermal, and solar PV. The study composes a list of “actions and actors” in different time frames to achieve the visions.

Option	Short term (2010)	Medium term (2010–2025)	Long term (>2025)
Biomass (1000 PJ in 2050 of which 800 PJ is imported)	* Finding international allies for co-operation and scaling-up of pilot plants * Government: creating favourable conditions regarding price of biomass in relation to cheap energy carriers * Industry/scientific institutes: eveloping technology and technological concepts * Government: creating level playing field * Consumers/service sector: illingness to pay more for ‘green’ electricity	* Starting pilot plants * In international climate policy (FCCC), carbon sinks are linked to biomass production	
Solar PV	* Formation of technological top institute (government, industry and science) * Stimulating market development for PV * Companies will be satisfied with lower profit margins * Government: Fiscal measures for technology push * Industry: Improving technology of PV, increasing efficiency with 50%	* Stimulating market development * Strengthening net infrastructure * Energy companies: Installing two meters at households, one for consumption, one for PVproduction of electricity * Standardising use of PV in newly build homes	* Creating large scale application of PV in Sahara * Faster implementation of PV in existing buildings
Wind energy	* Realisation of pilot off-shore wind park * Government continues steering role in stimulating wind energy	* Enlargement of societal acceptance by means of information and communication	* Realisation of large(r) scale off shore wind energy

9. Goteborg, Sweden "Goteborg 2050"

The project Göteborg 2050 develops visions of a future city and region of Göteborg in a sustainable world. Images of a long-term sustainable future are used in the project to stimulate and foster an accelerated movement towards sustainability using a methodology called "backcasting." The backcasting method involves four steps: (1) Analyse the present situation; (2) Examine and decide upon criteria for sustainability; (3) Create alternative scenarios; (4) Use the scenarios to promote change. The project GöTEBORG 2050 includes components of research, scenario development, support for strategic planning, dialogue with the public, visualizations, and support for demonstration projects.

The project is a co-operative effort between the Chalmers University of Technology and Göteborg University, the City of Göteborg with its municipal administration, and the city energy utility (Göteborg Energi AB) and other public municipal and regional companies.

The project is active in a number of planning processes in the City of Göteborg and the Göteborg region, using the backcasting method. It supplies visionary and sustainability-focused input into the development of a new energy plan for the city. It is also active in the planning processes for the city's urban planning and the city's waste management planning. The project is also supplying visionary input in a process where the Göteborg region is evaluating sustainable transportation futures. The project also reaches into the areas of building construction, time use, industrial development, food, and consumption of goods and services.

Underlying all scenario work in the project is the understanding that social sustainability, The Good Life, is just as important as reaching environmental sustainability. Another important goal for the project is to have an outreach to the general public. Through exhibitions, meetings, media interaction and information work we reach out to the citizens of Göteborg in order to show positive visions of a sustainable future. The project is also proactive in initiating demonstration projects that show the sustainable world already today.

10. Other Often-Cited Visions

- Shell, Energy Needs, Choices, and Possibilities. "Spirit of a New Age" means everyone has their own fuel cells at home and in vehicles and purchases hydrogen from centralized suppliers. Renewables play only a modest role until after 2050.

- Seth Dunn/Worldwatch, Micropower: The Next Electrical Era. A future vision where everyone produces their own power and renewables integrate with gas turbines, fuel cells, intelligent grid controls, and markets based on energy service instead of kWh.

- Walt Patterson, Transforming Electricity. Competing future visions of innovation and tradition. Country “Traditia” suffers from blackouts and is dependent on foreign fuels. Country “Innovatia” has restructured electric system to on-site distributed renewables.

- Hermann Scheer, A Solar Manifesto. Political, social, and institutional constraints and possible future innovations towards predominant use of solar energy. The choice is obvious, we just lack the right institutions and political will.

- Jeremy Rifkin, The Hydrogen Economy. Vision of a bright future where we all use hydrogen and fuel cells, where renewables provide the hydrogen, and where energy becomes decentralized, democratic, and community-oriented.

11. Conclusions

China’s proposed development targets include 10% of total primary energy from renewables by 2020. Table 6 compares this target with other international targets and scenarios.

Table 6: Comparison of Targets and Scenarios

Target/scenario	**Share of primary energy from renewables**	**Share of electricity from renewables**
China development target	5% by 2010 and 10% by 2020	10% by 2010 and 20% by 2020
EU target	12% by 2010	21% by 2010
U.S. state-level targets		5-30% by 2010-2012
Thailand target	8% by 2011	
Korea target		7% by 2010
Wind Force 12 scenario		12% by 2020 from wind
IEA “Sustainable Development (SD) Vision” scenario	35% by 2050	
Shell scenarios	30-50% by 2050	
Netherlands (ECN) scenarios	45-80% by 2050	

In addition, China’s target of 20% power generation from renewables is consistent with a 12% target from “Wind Force 12” coupled with additions of biomass power generation and continued growth of small hydro.

In the China Renewable Energy Roadmap Project, normative scenarios could be developed for fulfilling primary energy of 10% by 2020 and expanded upwards to 20-40% for the 2030-2050 timeframe, with detailed breakdowns of different technology shares, using some of the methodologies from the studies presented above and several additional studies. Different technology cases could be considered, for example a case where biomass plays the most important role, similar to the Netherlands scenario, or one where solar PV costs are lowered to an extent that solar PV plays an important role, similar to the U.S. NREL Solar Technology Roadmap.

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